STUDIES ON THE PHYSIOLOGY OF BAMBOO WITH REFERENCE TO PRACTICAL APPLICATION

I. PHYSIOLOGY

1. BAMBOO SPECIES

Bamboo and Sasa were formerly included in Graminae, but now they are both in Bambusaceae. Twelve hundred and fifty species of 47 genera are found in the world [1]. There are seen wide distribution and abundant volume of culms, though most of which, are of natural growth in South-East Asian countries, including China (Southern China), Formosa, Philippine, Thailand, Burma, India, Pakistan. Indonesia, and American countries etc.

No native bamboo species are found in Europe and very few in Australia.

In Japan, 662 species of 13 genera are found including Sasa. Bamboo species grow in southern part of Hokkaido and in every district of other island and more than twenty species are cultivated, producing a large yield.

Bamboo and Sasa are distinguished according to the peeling habit of culm sheaths. In bamboo, the sheaths drop off when the culms reach their full size, while in sasa they remain for long.

The typical species and varieties of Bamboo and Sasa are listed as follows.

A. Bamboo and Sasa (Bambusaceae) indigenous to or cultivated in Japan.[1][2][3]

i. Bamboo.

(1) Leleba (Bambusa)

Sympodial Type; rhizome very short, leaves not tessellate.

Locality: Tropical and temperate zones such as Japan, Formosa, Philippine, South China, Indo-China, Burma, East India, Brazil, etc. 3 species and 5 forms occur in Japan.

Typical species;

L. (Bambusa) floribunba Nakai; *HOO-CHIKU* (Common or local name)
L. floribunda Nakai form. viridi-striata Nakai; *BENIHOO-CHIKU*
L. multiplex Nakai; *HORAI-CHIKU* (*HOBI-CHIKU, KOKO-CHIKU, DOYO-CHIKU, CHIN-CHIKU*)
L. multiplex Nakai form. variegata Nakai; *HOSHO-CHIKU*
L. multiplex Nakai form. Alphonso-Kari Nakai; *SUHO-CHIKU*
L. Oldhami Munro; *RYOKU-CHIKU*
L. vulgaris Nakai; *DAISAN-CHIKU* (*RYUZU-CHIKU*)

(2) **Phyllostachys**

Sheaths caducous culms usually large, leaf-sheaths conspicuous, 2 (seldom 1) branches at a node, culms grooved on one side, stamens 3, inflorescence compound spikes.

Locality: Japan, China, Indo-China. 9 species, 13 forms and 14 varieties occur in Japan.

Typical species;

Phyllostachys bissetii McClure[4)]

P. dulcis McClure; *AMAHA-CHIKU*

P. edulis Riv.; *MOSO-CHIKU* (*KONAN CHIKU*) = P. heterocycla Matsum, var. pubescens Ohwi

P. edulis Riv. var. heterocycla Makino; *BUTSUMEN-CHIKU*

P. edulis Riv. var. heterocycla Makino form. subconvexa Makino; *KIKKO-CHIKU*

P. edulis Riv. form. aureo-striata Uchida; *SHIMAMOSO*

P. Makinoi Hayata; *KEI-CHIKU* (*TAIWANMA-DAKE*)

P. nigra Munro; *KURO-CHIKU*

P. nigra Munro form. nigro-punctata Makino; *GOMA-DAKE*

P. nigra Munro form. bicolor Makino; *SOMEWAKE-DAKE*

P. nigra Munro var. Henonis Stapf.; *HA-CHIKU*

P. nigra Munro var. Henonis Stapf. form. Boryana Makino; *TANBA-HAN-CHIKU* (*UNMON-CHIKU*)

P. nigra Munro var. Henonis Stapf. form. Megurochiku Makino; *ME-GURO-CHIKU*

P. nigra Munro var. tosaensis Makino; *TOSATORAFU-DAKE*

P. humilis Muroi; *HIMEHA-CHIKU*

P. aurea Carr.; *HOTEI-CHIKU* (*GOSAN-CHIKU, KURE-TAKE*)

P. aurea Carr. form. albo-variegata Makino; *SHIMAHOTEI-CHIKU*

P. aurea Carr. form. alternato-lutescens Makino; *GINMEIHA-CHIKU*

P. reticulata C. Koch; *MA-DAKE*=P, bambusoides Sieb, et Zuce.

P. reticulata C. Koch var. Castillonis Makino; *KINMEI-CHIKU*

P. reticulata C. Koch var. Marliacea Makino; *SHIBO-CHIKU*

P. reticulata C. Koch var. sulphurea Makino; *OGON-CHIKU* (*KIN-CHIKU*)

P. reticulata C. Koch form. Tanakae Makino; *HYUGAHAN-CHIKU*

P. reticulata C. Koch form. Kashirodake Makino; *KASHIRO-DAKE*

P. reticulata C. Koch form. Kawadana Makino; *KISHIMA-DAKE*

P. reticulata C. Koch form. subvariegata Makino; *KONSHIMA-DAKE*

P. reticulata C. Koch form. geniculata Nakai; *MUTSUORE-DAKE*

P. tranquillans Muroi; *INYO-CHIKU*

(3) Semiarundinaria

Sheaths caducous culms medium in size. 3-6 branches at a node; branches almost in bundles. Culms cylindrical without grooves, inflorecence simple spikes, outer glumes abortive.

Locality: Japan, Hainan Island, etc. 8 species occur in Japan.

Typical species;

Semiarundinaria fastuosa Makino; *NARIHIRA-DAKE* (*DAIMYO-CHIKU*)

S. fastuosa Makino var. viridis Makino; *AONARIHIRA*

S. Kagamiana Makino; *RIKUCHU-DAKE*

S. Tatebeana Muroi; *KENASHIYASHA-DAKE*

S. villosa Muroi; *BIRODONARIHIRA*

S. Yashadake Makino; *YASHA-DAKE*

S. Yoshi-Matsumurae Muroi; *NIKKONARIHIRA*

(4) Sinobambusa

Similar to Semiarundinaria, differs, however, in having long purplish hairs at the node of young culms, and side branches longer than 1/2 of the main branch. Culm sheaths ciliate, internodes long; outer glume present.

Locality: Japan, Ryukyu, and Burma. 1 species 1 form occur in Japan.

Sinobambusa tootsik Makino; *TO-CHIKU*

S. tootsik Makino form. albo-striata Muroi; *SUZUKONARIHIRA*

(5) Tetragonocalamus

Culm-sheaths caducous. Cross section of culm square, aerial roots at the lower nodes, Culm-sheaths without appendages, sprouts in Sep.-Nov. Locality: China (Fu-kien, Kiang-su), native to Formosa.

1 species and 1 forma occur in Japan.

Typical species;

Tetragonocalamus quadriangularis Nakai; *SHIKAKU-DAKE* or *SHIHO-CHIKU*

(6) Chimonobambusa

Culm-sheaths caducous leaf-sheaths conspicuous; branches more than 3 at a node; culm purplish, aerial roots at the lower nodes. Sprouts in Sept.-Nov.

Locality: China (origin), Japan. 1 species and 1 forma occur in Japan.

Chimonobambusa marmorea Makino; *KAN-CHIKU*

C. marmorea Makino var. variegata Makino; *CHIGOKAN-CHIKU*

(7) Shibataea

Culm-sheaths caducous leaf-sheaths not developed; branchlets short, short branches 3-5 at each node. Culms slender and low; groove on one side at the base of internode.

Locality: Japan. 1 species.

Shibataea kumasaca Nakai; *OKAME-ZASA*

ii. Sasa

(8) Pseudosasa

Culm-sheaths persistent; branch at each node. Culm-sheaths longer than internode, surpassing next node.

Locality: Japan, Ryukyu and Korea. 2 species and three forms occur in Japan. Typical species;

Pseudosasa japonica Makino; *YA-DAKE*

P. japonica Makino var. Tsutsumiana Yanagida; *RAKKYO-CHIKU* (*RAKKYO-YADAKE*)

P. japonica Makino var. flavovariegata Makino; *KISHIMAYA-DAKE*

P. Owatari Makino; *YAKUSHIMA-DAKE*

(9) Pleioblastus (Arundinaria)

Culm-sheaths persistent, enveloping culm for a long time, culms smaller of medium size. 3-5 branches at each node, branching in the second year. Oval setae flexuose, glabrous, white, stamens 3. Empty glumes large.

Locality: Japan, Ryukyu and China. 93 species occur in Japan. Typical species;

Arundinaria amabilis McClure; (S. China)

Pleioblastus akasiensis Koidz.; *AKASHINE-ZASA*

P. akebono Nakai; *AKEBONO-ZASA*

P. angustifolius Nakai; *HIMESHIMA-DAKE*

P. Chino Makino; *AZUMANE-ZASA*

P. Communis Nakai; *GOKI-DAKE*

P. epitrichus Koidz.; *UWAGENE-ZASA*

P. Fortunei Nakai; *CHIGO-ZASA*

P. gramineus Nakai; *TAIMIN-CHIKU*

P. Hindsii Nakai; *KANZAN-CHIKU*

P. hodensis Makino; *HODEN-ZASA*

P. Kongosanensis Makino; *KONGO-DAKE*

P. lanatus Nakai; *KAWAMURA-ZASA*

P. linearis Nakai; *RYUKYU-CHIKU* (*YANBARU-CHIKU*)

P. longaevus Koidz.; *KUMANE-ZASA*

P. multifolius Nakai; *CHOJA-ZASA*

P. pubescens Nakai; *KENE-ZASA*

P. pumilus Nakai; *IYOSUDARE*

P. pygmaeus Nakai var. distichus Nakai; *OROSHIMA-CHIKU*

P. Simoni Nakai; *ME-DAKE*

P. Simoni Nakai var. heterophyllus Nakai; *HAGAWARIME-DAKE (TSU-SHI-CHIKU)*

P. Uyenoensis Nakai; *UENO-ZASA*

P. vaginatus Nakai; *HAKONE-DAKE*

P. viridi-striata Makino; *KAMURO-ZASA*

P. xestrophyllus Koidz.; *KEZAYANOGOKI-DAKE*

P. yoshidake Nakai; *NE-ZASA*

P. yoshidake Nakai var. Tsuboi Nemoto; *UEDA-ZASA*

(10) Nipponobambusa

Culm-sheaths persistent, 3 branches at each node. Oval stout. Resembles Pleioblastus, differs, however, in having 6 stamens.

Locality: Only in Japan (main island). 12 species and 1 forma occur in Japan.

Typical species;

Nipponobambusa nikkoensis Muroi; *KIRIFURI-ZASA*

N. Reikoana Muroi; *REIKOSHINO*

N. Sasakiana Muroi; *TOGE-ZASA*

N. Sawadai Muroi; *HAKONEME-DAKE*

(11) Sasamorpha

Culms-sheaths persistent; culms sparse. One branch at each node. Oval setae stout, glabrous; ligule triangular, culm-sheath equal in length to or longer than internode. stamens 6.

Locality: Only in Japan (main island).

Sasamorpha purpurascens Nakai; *SUZU-DAKE*

S. amabilis Nakai; *KUMA-SUZU*

S. mollis Nakai; *KE-SUZU*

S. Uinuizoana Koidz.; *HOSOBA-NANBU-SUZU*

(12) Sasaella

Culm-sheaths persistent; one branch at each node, and branches in the first year. Culm up to 2 m high. Stamens 6 (often 4-5). Oval setae straight, rough, well developed.

Locality: Japan (Honshu "main island" Shikoku, and Kyushu).

Abundant in Kanto and Tohoku Districts. 132 species occur in Japan.

Typical species;

Sasaella Arakii Makino; *MITAKE-SHINO*

S. stamiana Makino; *ATAMINE-ZASA*

S. atro-purpurea Makino et Nakai; *MURASAKISENDAI-SHINO*

S. glabra Muroi; *SHIYA-ZASA*

S. Hashimotoi Muroi; *OSAKA-ZASA*

S. hidaensis Nakai; *HISHU-ZASA*

S. mikurensis Nakai; *MIKURAKO-ZASA*
S. okadana Makino; *HIROHAAZUMA-ZASA*
S. ramosa Makino; *AZUMA-ZASA*
S. suwekoana Makino; *SUEKO-ZASA*
S. tangoensis Muroi; *TANGO-ZASA*

(13) **Sasa**

Culm-sheaths persistent; culms small. One branch at each node. Inflorescence paniculate, longly stalked. Leaf-margin turn white in winter in many spp. Stamens 6; stigma 3-furcate.

Locality: Southern Saghalien, Hokkaido, Honshu, Shikoku, Kyushu, and Korea. over 400 species occur in Japan.

Typical species;

Sasa amagiensis Makino; *AMAGI-ZASA*
S. Asahinae Makino et Nakai; *GOTENBA-ZASA*
S. chartacea Makino et Shibata; *OKUMA-ZASA*
S. futatabiensis Koidz.; *FUTATABIKOSUZU*
S. geniculata Koidz.; *NASUNOMIYAKO-ZASA*
S. gracillima Nakai; *UNZEN-ZASA*
S. hastatophylla Muroi; *YARIKUMA-ZASA*
S. Kurilensis Makino et Shibata var. yezoensis Tatewaki; *EZONEMA-GARI*
S. Kurokawana Makino; *IGA-ZASA*
S. nipponica Makino et Shibata; *MIYAKO-ZASA*
S. nipponica Makino et Shibata
form. robustior Makino; *KEKUMA-ZASA*
S. nobilis Nakai; *KINTAI-ZASA*
S. paniculata Makino et Shibata; *NEMAGARI-DAKE*
S. paniculata Makino et Shibata var. ontakensis Camus.
form. nebulosa Nakai; *SHAKOTAN-CHIKU*
S. perexuguoseta Koidz.; *FUSHIGEATSUBA-ZASA*
S. sendaica Makino; *SENDAI-ZASA*
S. Shimidzuana Makino; *HAKONE-SUZU*
S. tyuhgokensis Makino; *TYUGOKU-ZASA*
S. Veitchii Rehd.; *KUMA-ZASA*

B. Bamboo in foreign countries[5)6)7)8)]

Among bamboo species found in foreign countries, some of their species and varieties alone will be listed.

(1) Arthrostylidium capillifolium Griseb; Locality; North America, Mexico,

Cuba, Brazil.

(2) Arundinaria Monopodial type.

A. elegans Kurz; Locality ; Burma.

A. gigantea Chapm.; Locality; U. S. A.

A. Sat Balansa; Locality; Cambodia, Laos, and Viet-Nam.

A. tecta Muhlenb.; Locality; U. S. A.

A. Wightiana Nees; Locality; India.

(3) Athroostachys Benth.; One species is found in Brazil.

(4) Atractocarpa Franch.; One species is found in Brazzaville.

(5) Aulonemia Goudot; One species is found in Venezuela.

(6) Bambusa; Sympodial type (clump-form).

Branchlets with spines;……………Bambusa

Branchlets without spines; ………Leleba

B. arundinacea Willd.; *MULU*, 20 cm in diameter; Used for construction. Locality; India, Pakistan, Burma.

B. Bambos Druce; 20 cm in diameter; young shoots edible. Locality; India, Indonesia.

B. procera A. Chev.; Locality; Malaya.

B. spinosa Roxb.; 20 cm in diameter; used for construction. Locality; Philippine, Borneo, Indonesia.

B. stenostachya Hack.; *SHICHIKU* 7 cm in diameter; Used for construction and windbreaks. Locality; Formosa.

B. tuldoides Munro; Locality; Brazil, India (Assam).

(7) Brasilocalamus Nakai; One species is found in Brazil.

(8) Cephalostachyum;

C. capitatum Munro; a climbing form; Culms are used for making bows; leaves serve as cattle feed. Locality; India.

C. mindorense Gamble; a climbing form; Locality; Philippine.

C. pergracile Munro; erect form; Locality; Burma, China.

(9) Chusquea Kunth; Locality; America, Mexico, Brazil.

(10) Dendrocalamus; Sympodial type (Clump-form).

D. asper Backer; Young shoots edible; culms used for construction. Locality; Cambodia, Viet-Num, Malaya, Indonesia, Borneo.

D. Brandisii Kurz; Building material; diameter 20 cm, Locality;Thailand, Burma, Cambodia, Viet-Nam.

D. giganteus Munro; Building material; Locality; Thailand, Burma, Cambodia, Viet-Nam, Malaya.

D. Hamiltonii Nees; *KAKO*, Locality; India (Assam), Burma.

D. latiflorus Munro; *MA-CHIKU*, Building material; young shoots edible. Locality; Thailand, Burma, Philippine, Formosa.

D. Merrillianus Elm.; Building material; Locality; Philippine.

D. strictus Nees; Pulp and others; Locality; India, Burma.

(11) Dinochloa; a climbing form; Material for baskets.

D. pubiramea Gamble; Locality; Philippine, Borneo.

D. Maclellandii Kurz; Locality; Cambodia, Laos, Viet-Nam.

D. scandens O. Kuntze; Locality; Philippine, Indonesia, Borneo.

(12) Fargesia Franchet; One species is found in China.

(13) Gigantochloa; edible young shoots.

G. Apus Kurz; Locality; Indonesia, Borneo.

G. laevis (Blanco) Merr.; Diameter 20 cm; Locality; Philippine.

G. nigrociliata Kurz; (Batu) Locality; Indonesia.

G. Scribneriana Merr.; Diameter 20 cm; Locality; Laos, Cambodia.

G. verticillata Munro; Diameter 15 cm; Locality; Indonesia, Cambodia.

G. wrayi Gamble; Locality; Malaya.

(14) Glaziophyton Franch.; One species is found in Brazil.

(15) Greslania Balansa; Locality; New-Caledonia.

(16) Guadua Philippinensis Gamble; Utility limited; Locality; Philippine.

G. angustifolia Kunth; Locality; Colombia, Ecuador.

G. superba Huber; Locality; Brazil.

(17) Guadella Franch.; Locality; Africa.

(18) Indocalamus Nakai; Locality; China, Philippine.

(19) Bambusa(Leleba) dolichoclada Hayata; *CHOSHI-CHIKU*, Building materials and others. Locality; Formosa.

Bambusa (Leleba) multiplex Raeusch.; *HORAI-CHIKU* Building material; young sprouts edible. Locality; Formosa, Philippine, Indonesia.

B. (Leleba) Oldhami Munro; *RYOKU-CHIKU*, Edible (delicious). Paper; young sprouts delicious. Locality; Formosa.

B. (Leleba) Tulda Roxb.; Diameter 18 cm; paper and others. Locality; India, Burma and Thailand.

B. (Leleba) vulgaris Schrad. et Wendl.; *DAISAN-CHIKU*, Used for construction and others. Locality; Formosa, Indonesia.

(20) Melocanna;

M. bambusoides Trin.; *MULI*, Locality;India (Assam), Burma.

M. humilis Kurz; Locality; Burma.

(21) Melocalamus;

Melocalamus compactiflorus Benth.; Locality; India (Assam).

(22) Merostachys Spreng.; Locality; Brazil, Peru.

(23) Microcalamus Franch.; One species is found in West-Africa.

(24) Nastus Jussieu; Locality; Brazil, Sumatra.

(25) Neohouzeaua;

Neohouzeaua Dullooa A. Camus; Internode-length 1 m. used for making bamboo wares; Locality; India, Laos, Indonesia.

(26) Ochlandra;

Ochlandra Ridleyi Gamble; Paper and pulp; Locality; Thailand, Malaya, India, Indonesia.

(27) Oreiostachys Gamble; One species is found in Indonesia.

(28) Oreobambus Schum. ; One species is found in Africa (Usumbura).

(29) Oxytenanthera;

O. nigro-ciliata Munro; Diameter 10 cm; Locality; Laos, India, Burma, Cambodia, Thailand, Viet-Nam.

O. parvifolia Brandis. ; (Bambusa palida), Hill Jati, Paper and others; Locality; India (Assam), Thailand, Burma.

O. Poilanei A. Camus; Used for making baskets; Locality; Cambodia, Thailand.

O. Stocksii Munro; Locality; India, Burma, Cambodia, Viet-Nam.

(30) Planotia Munro; Locality; South-America, New-Guinea.

(31) Pleioblastus Nakai; Locality; China (Hong-Kong).

(32) Phyllostachys (Sinoarundinaria); monopodial type (Single culm).

P. aurea Carr. Locality; Indonesia.

P. Makinoi Hayata; Locality; Formosa.

P. Mannii Gamble; Locality; India (Shillong).

P. pubescens Mazel; Locality; Cambodia, Laos, Viet-Nam, China.

P. reticulata K.Koch; Locality; Cambodia, Laos, Viet-Nam, China.

(33) Pseudosasa Makino; Locality; Korea.

(34) Pseudostachyum;

Pseudostachyum polymorphum Munro; Bein soft; used for making baskets and others; Locality; India, Burma.

(35) Puelia Franchet; Locality; West-Africa, Congo, Gabun.

(36) Sasa Makino et Shibata; Locality; Korea, Saghalien, China.

(37) Sasamorpha Nakai; Locality; Korea; South-China.

(38) Schizostachyum;

S. Blumei Nees; a climbing form; Locality; Pakistan, Cambodia, Viet-Nam, Indonesia.

S. brachycladium Kurz; Locality; Indonesia.

S. diffusum Merr.; a climbing form; Locality; Philippine.

S. Lumampao Merr.; (*BUHO*), Most fitted for pulp production. This is found mostly in Philippine.

S. latifolium Gamble; Locality; Indonesia.

(39) Semiarundinaria Makino; Locality; South-China.

(40) Shibataea Makino; Locality; China.

(41) Teinostachyum;

T. dulloa Munro; Locality; Dalu India (Assam).

T. Griffithii Munro; Used for basket, leaves fitted for cattle feed.
Locality; Burma, Thailand.

(42) Tetragonocalamus Nakai; Locality; China, Korea.

(43) Thamnocalamus Munro, Locality; Northern India.

(44) Thyrsostachys;
Thyrsostachys siamensis Gamble; Locality; Thailand, Cambodia, Laos.

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2. Development of Bamboo

The vigorous propagation of bamboos mainly takes place asexually in the form of branching of rhizomes. Accordingly, the propagation form of bamboos are classified into three types as follows (**Fig. 1**).

1. Monopodial type

The rhizome which has one bud at each node develops monopodially every year. Namely, some of these buds grow into sprouts which appear on the ground at a certain distance. Then, newly grown culms take the single-culm formation. Many of the bamboo species grown in Japan belong to this type.

The culms are erect and the branchless height (clear length) is generally high.

2. Sympodial type

The apex of the rhizome which has nodes, but no buds such as monopodial type at them, protrudes out of the ground and grows into a culm. In the following year, the bud on the basal part of the culm develops into a short rhizome, which protrudes out of the ground to make a secondary culm, thus forming a clump culm. The clump formation takes place in *Lelcba* species in Japan and many other species in tropical regions, while *Melocanna* species have long rhizomes which form a single culm.

Some of the species in tropical regions, such as *Dendrocalamus strictus,* have a thick wall culm.

Some of the species take the climbing form and the branchless height is generally low.

3. Intermediate type

Species such as *Sasa paniculata,* in Japan, show an intermediate type between monopodial and sympodial.

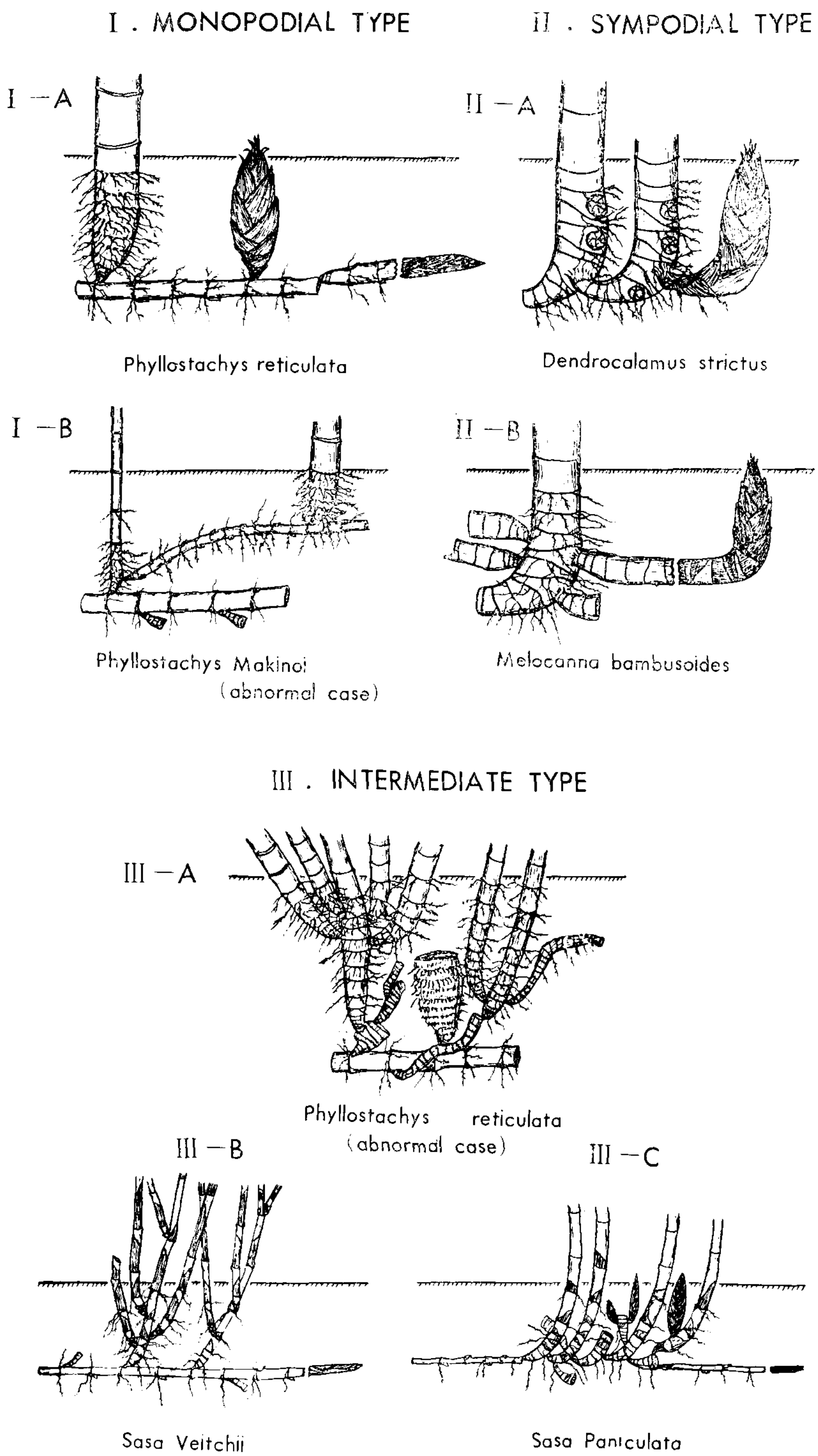
However, these types may change according to the environmental condition, as shown in photographs 12 and 40.

A. Growth

A-1. Growth of culm

A bamboo sprout, which is called *Takenoko* in Japanese, is covered with sheaths, and grows very fast until it completes the full size of its culm

Fig. 1. Branching system of rhizome



within several months.

a. Emerging period of bamboo sprout

The buds on rhizome-nodes swell slowly and continuously for several months in the soil.

The period of sprout-emergence out of the ground varies according to the species, vigour of the mother bamboo, and also the environmental condition of the locality. Even in one bamboo grove, however, there are variation of fifty to sixty days between early and late-sprouting. The sprouting, however, is affected by the precipitation. When the precipitation is low the number of sprouts decreases especially in its best season. The emerging periods of sprouts in Kyoto are as follows; (according to 1954–1958 observations).

From the beginning to the middle of March···*Pleioblastus* (*Arundinaria*), *Sasa*.

From the end of March to the beginning of April···*Phyllostachys edulis*

From the middle to the end of April···*Ph. nigra, Ph. nigra var. Henonis, Ph. Makinoi*, etc.

From the beginning to the middle of May···*Ph. reticulata, Semiarundinaria, Leleba vulgaris*, etc.

From the end of May to the beginning of June···*Ph. reticulata form. Kashirodake*

From the end of July to the beginning of August···*Leleba* (*Bambusa*) *floribunda, Leleba multiplex*[1], etc.

From the beginning to the middle of October···*Chimonobambusa, Tetragonocalamus*, etc.

The data regarding the emergence of sprouts and their growth in *Ph. edulis* (*MOSO-CHIKU*) and *Ph. reticulata* (*MADAKE*) are shown in the following table.

Table 1. By date of sprout-appearance, number of total sprouts, undeveloped sprouts and fully developed culms.

(1) *Phyllostachys edulis* (area: 0.1 ha)

Period of sprouting	Before – Mar. 25	Mar. 26 – Apr. 1	Apr. 2 – Apr. 8	Apr. 9 – Apr. 13	Apr. 14 – Apr. 18	Apr. 19 – Apr. 25	Apr. 26 – May 4	May 5 – May 13	Total
Total number of sprouts	51	53	73	85	104	56	14	10	446
Number of undeveloped sprouts	39	35	56	61	86	53	12	10	352
Fully developed culm: Number	12	18	17	24	18	3	2	0	94
Fully developed culm: Diameter at eye height (cm)	10.0	9.6	9.4	9.4	8.7	8.6	7.1		

Locality: Fushimi, Kyoto. (1955)

(2) *Phyllostachys reticulata* (area; 0.1 ha)

Period of sprouting	May 30 – June 1	June 2 – June 4	June 5 – June 7	June 8 – June 12	June 13 – June 16	June 17 – June 22	June 23 – June 30	July 1 – July 12	Total
Total number of sprouts	4	20	64	134	100	60	12	4	398
Number of undeveloped sprouts	2	0	12	56	48	38	8	2	166
Fully developed culm: Number	2	20	52	78	52	22	4	2	232
Fully developed culm: Diameter at eye height (cm)	4.0	4.0	4.5	4.2	3.7	2.7	2.6	2.3	

Locality: Mukomachi, Kyoto. (1956)

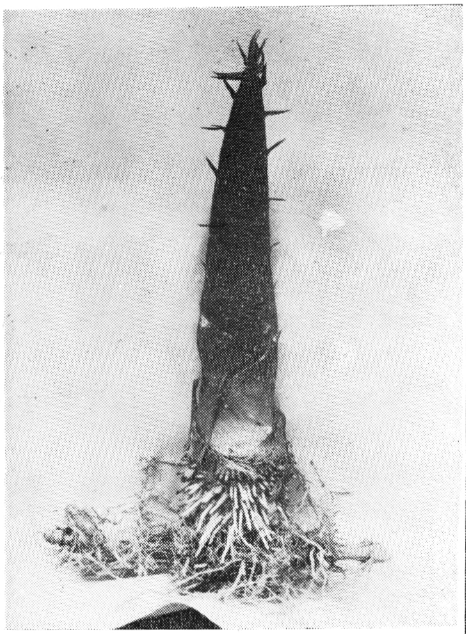


Photo. 3

Beginning of root development of *Phyllostachys edulis* sprout.

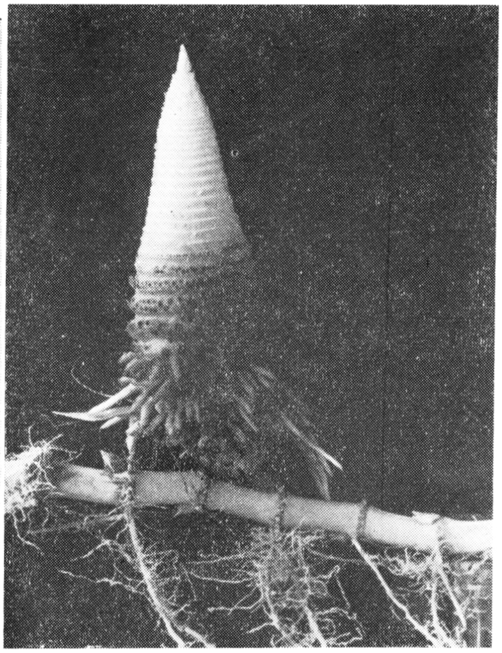


Photo. 4

Phyllostachys edulis sprout which has shed its sheath. (see the number of nodes of a sprout).

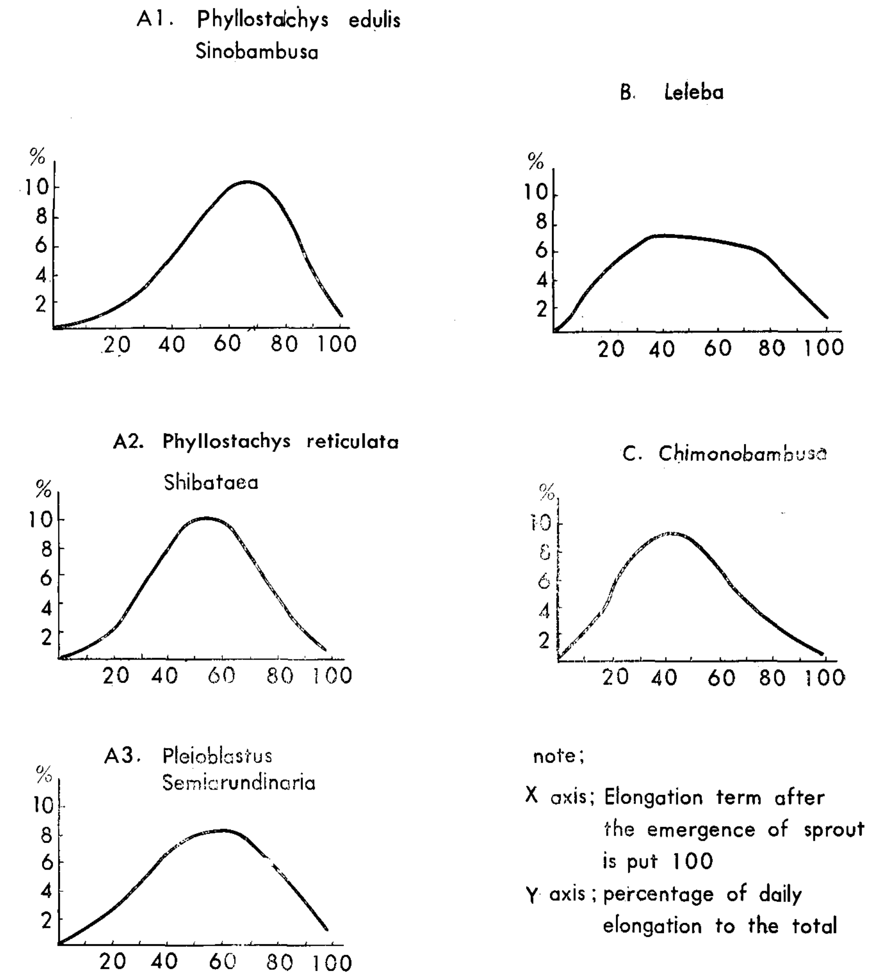
Generally speaking, early sprouts tend to develop into larger culms with superior quality, while late sporuts, smaller culms with inferior quality.

b. Process of growing

After sprouts' appearance on the ground, the growth of sprouts slow at the beginning, but gradually gains speed, up until the culms attain the maximum size, and slow down thereafter (Fig. 2-b). The growth curves have been classified into Type A_1, A_2, A_3, B and C as shown in Fig. 2-a by Prof. Y. Shigematsu[2] of Miyazaki University. He has reported that spring sprouts show Type A curves, and summer and autumn sprouts Type B and C curves respectively.

Fig. 2-a. Growth curve of bamboo sprouts

by Prof. Y. Shigematsu



Most of the above mentiond phenomena have been affirmed by the author by accurate measurements for six years since 1952.

However, those sprouts of clump-forming species of sympodial type such as *HORAI-CHIKU* (*Leleba multiplex*) which emerge in summer grow inch by inch over a long period of time (Fig. 2-c). *KAN-CHIKU* (*Chimonobambusa*) whose sprout emerges in autumn, shows a growth curve similar to that of *Leleba*, but in the Kyoto area its growth stops in winter because the tops wither owing to cold temperature.

c. Period for growing to perfection

The sprout reaches its full diameter and full length in 30–110 days after the appearance on the ground, and thereafter the culm never increases in diameter or height. The growing period of culm is about 30–80 days in single-culm species of monopodial type, while it is 80–110 days for clump-forming ones of sympodial type.

The growth of culms takes place at two periods in the species of monopodial type; namely,

i) The greater part of the culm is formed in the main growth-term of culm as shown in Table 2 (A), (1). The ratio of the length of this greater part to whole length is about 93%.

ii) The top part which has an extremely short internode, finishes development in the following growth-term of the culm as shown in Table 2 (A), (2). The ratio of the length of this top part to whole length is about 7 %.

The former grows vigorously, but the latter grows slowly, growing about 10 cm in two weeks. Table 2 shows the growth period of culms based on the above mentioned view points. Therefore, to take into account the growth of culm, the former (1) period only is more practical.

In the species, growing in summer and autumn, the above two periods can not be distinguished clearly as culm grows slowly and continuously (Table 2 (B), Fig. 2 b, c.).

Table 2. Growth-term of *Phyllostachys edulis, Ph. reticulata* and *ph. nigra.*

(A)

Species	(1) Growth-term of the greater part of a culm		(2) Following growth-term of the top part of culm		(1)+(2) Total growth-term (term of complete growth)	
	Early sprout (days)	Late sprout (days)	Early sprout (days)	Late sprout (days)	Early sprout (days)	Late sprout (days)
Ph. edulis	30—50	25—35	about 30	about 25	60—80	50—60
Ph. reticulata	20—30	about 20	about 25	about 20	40—60	30—50
Ph. nigra	30—50	20—30	about 20	about 15	50—70	30—50

(B)

Genus	Growth-term	
	Early sprout (days)	Late sprout (days)
Leleba	87—110	88—101
Chimonobambusa	63	52

Locality: Kyoto (1952~'57)

Fig. 2-b. Daily elongation of early and late appearing sprout of *Ph. edulis* and *Ph. reticulata* in 1956 at Kamigamo-Experimental station

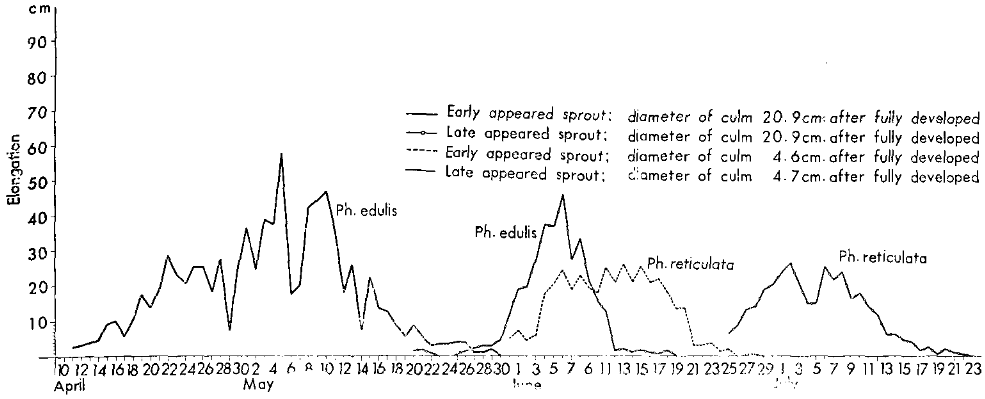
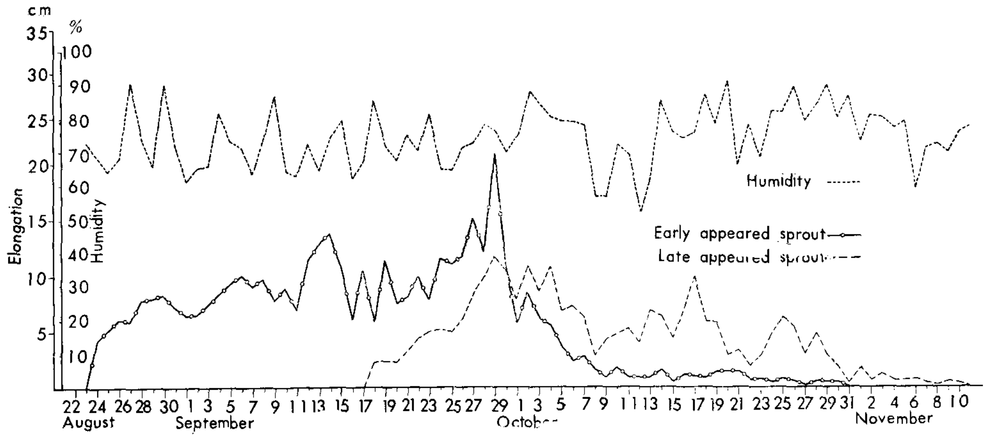


Fig. 2-c. Relation between daily humidity and daily elongation of early and late appearing sprout of *Leleba multiplex* in 1955, Kamigamo, Kyoto



Growing period is longer for early sprouts, and shorter for late sprouts (Table 2). For instance, for *Phyllostachys edulis*, periods of the growth of the greater parts of culm as shown above are 30 to 50 days for early sprouts, and 25 to 35 days for late sprouts.

d. Daily growth

Each internode has the growing zone. On this phenomenon the author confirmed by the experiment that even though the apex of a sprout is cut off, the elongation of the remnant growing portion does not stop (Table 3 photo. 5 and 6). Therefore, the daily growth of culm is the total of the daily elongation of the internodes. The internodal growth is completed successively upward starting from the basal internode. This is easily understood by observing that culm sheaths peel off from its base. Because it is confirmed that the growth of the internode is complete when the culm sheaths peel off slightly.

Table 3. Cutting length of a sprout apex and the growth of the remaining sprout of *Phyllostachys edulis*

Sprout	May 8, 1956			December 2, 1956						
	Length of sprout (cm)			Number of nodes		Fully elongated culm affer cutting apex			Fresh weight (g)	
	Initial part	Cutting part	Remaining part	Cutting Part	Remaining part	Diameter at eye heigtht (cm)	Whole length (cm)	Clear length (cm)	Culm	Branches and leaves
D	245	35	210	15	34	7.2	6.15	3.15	8,900	3,200
25	225	30	195	15	41	7.6	9.05	3.20	12,000	5,200
5	125	20	105	0	38	7.7	7.48	2.90	10,100	4,500
Control	294	—	294	—	46	7.7	10.50	3.60	12,150	4,200

Locality: Kyoto

Note: clear length is length of culm from its base to the first branch.

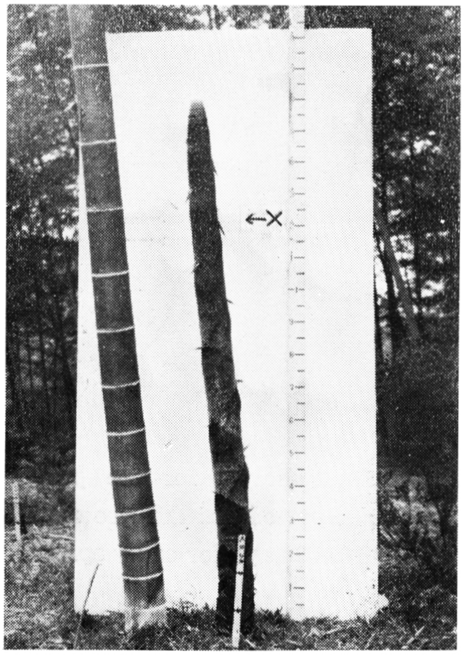
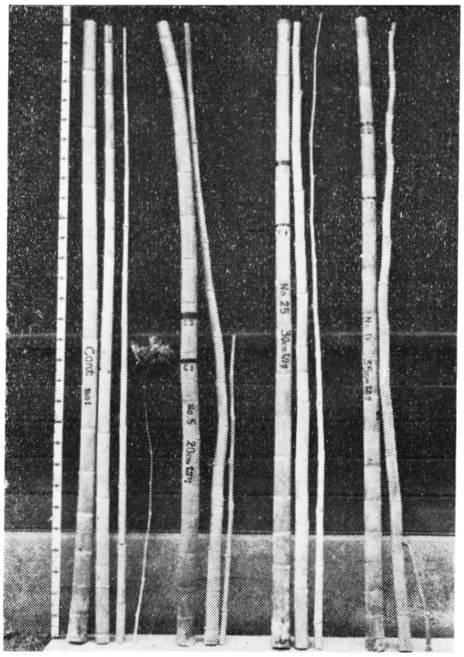


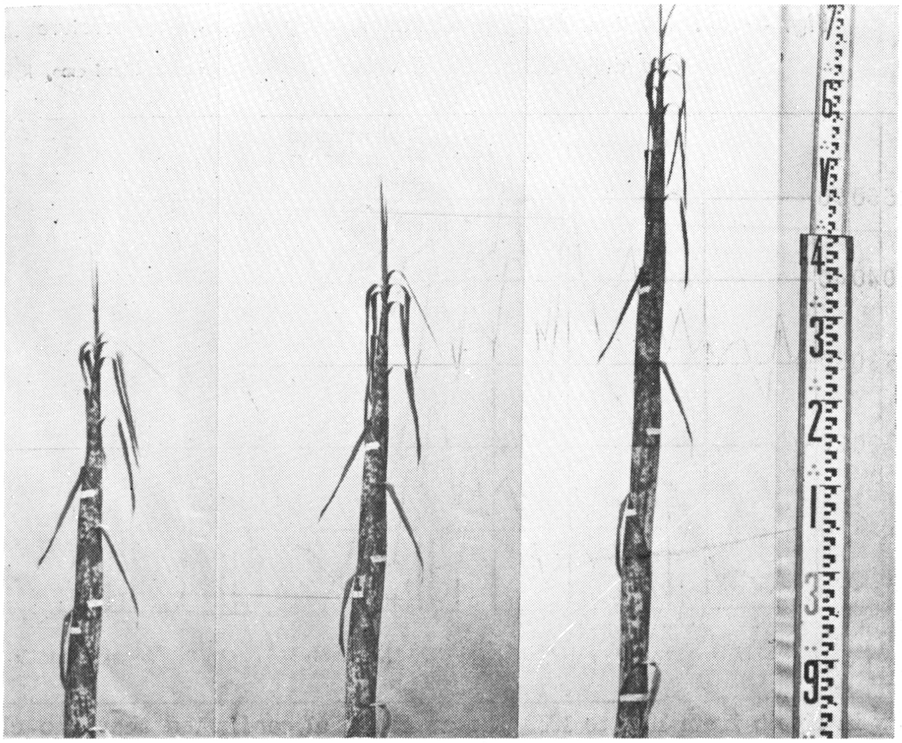
Photo. 5. The upper part above the X mark, showing the cutting off point at 11:00 a. m. on April 27, 1960, is the part elongated in 47 hours after cutting. The cutting portion was 20 cm and the remainder is 123 cm in length. Species: *Ph. edulis*.



Control No 5 No 25 No D

Photo. 6. The growth of the remaining part of sprouts. (See Table 3 for description)

Scale is marked at 5 cm intervals



time, 11:30 June 19 | 15:30 June 19 | 11:00 June 20

Photo. 7

Photograph showing the growth of a young sprout of *Phyllostachys reticulata* from 11:30 a.m. on June 19 to 11:00 a.m. on June 20 in 1957, at Kamigamo, Kyoto.
This mature culm attains to 6.8 cm in diameter at eye height and 10.50 m in length.

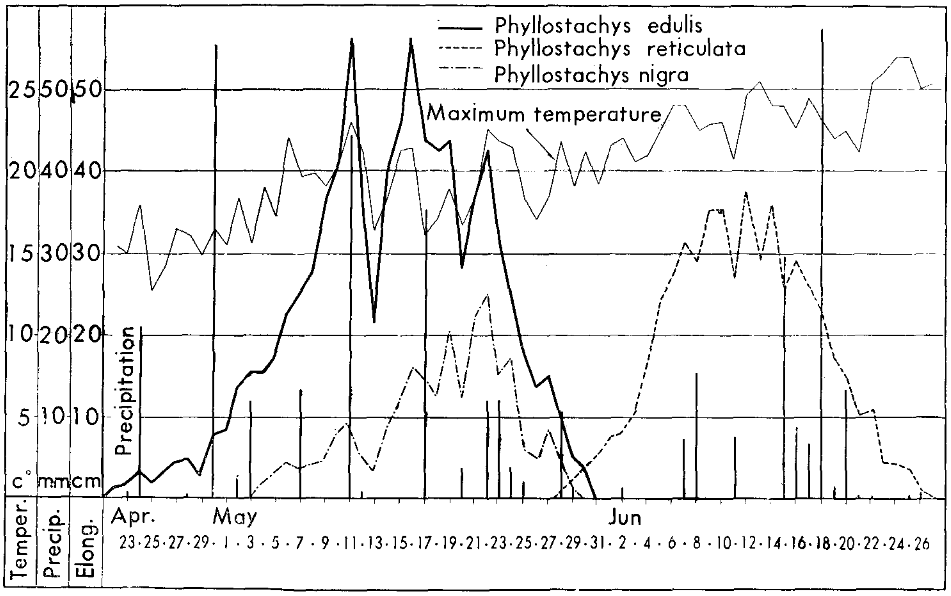
Prof. Y. Shigematsu[5] found that the daily growth is correlated positively with temperature and negatively with humidity. It has been also confirmed by the author et al[6] that the growth of bamboos is affected by the daily maximum temperature during or before the season when sprouts grow most vigorously. The data are based on the observations of 20 bamboos during six years from 1952. (Fig. 3-(a)).

In the genus *Phyllostachys* which sprouts in spring, the growth of a sprout during day'time is about the ratio of two thirds to the whole day growth. Usually a sprout grows more during the day'time than during the night. On the contrary, *HORAI-CHIKU* (*Leleba multiplex*), a tropical type, that sprouts in summer, grows more during the night in many cases, even in Kyoto (Fig.3-(b)).

It is said that in India, the sprouts of *Dendrocalamus strictus* grow during the night two times as much as during the day'time. Smith Went[7] and Osmaston measured the growth of sprouts of the sympodial type in Ceylon Island, and reported that humidity has a greater effect on the growth of sprouts than temperature does. Through the observation on the growth of *Leleba multi-*

Fig. 3-(a). Relation among precipitation, daily maximum temperature and daily elongation of culms

Locality: Kamigamo, Kyoto. 1956



plex in Kyoto from 1956 to 1959, the author et al confirmed that the elongation is affected by humidity, though it is not clear in the beginning and towards the end of the growth (Fig. 2 c). This is probably because the temperature in summer is not too low for the growth, thus it is likely to be affected by humidity.

The **maximum growth** per day (24 hours) comes to be found in the vigorous growing period. According to the up-to-date records, the largest growth per day (24 hours) is 91.3 cm by *Bambusa arundinacea* observed at Kew Garden[8] in England (1855), and 88.0 cm by *Phyllostachys edulis* which K. Shibata observed at Koishikawa Botanical Garden in Tokyo (1898). The author[9] recorded the growth 119 cm and 121 cm per day by *Ph. edulis* and *Ph. reticulata* respectively, in Nagaoka, Kyoto Pref., in 1955 and '56 (Table 4). The daily growth during several days is shown in Fig. 4. Such a remarkable growth could never be seen in any other plants.

Table 4. Maximum growth of a culm per day (24 hours)

Species	Date of sprouting	Maximum length of growth per day		Height of its culm		Its culm fully developed	
		(cm)	Date	(m)	Date	Diameter at eye height (cm)	Total length of a culm (m)
Phyllostachys edulis	Early in April 1956	119	May 24	13.90	May 24	15.4	21.00
Phyllostachys reticulata	Middle of May 1955	121	June 23	11.26	June 23	11.6	18.59

Locality: Nagaoka, Otokuni, Kyoto

Fig. 3-(b). Elongation of bamboo culm during the daytime and night

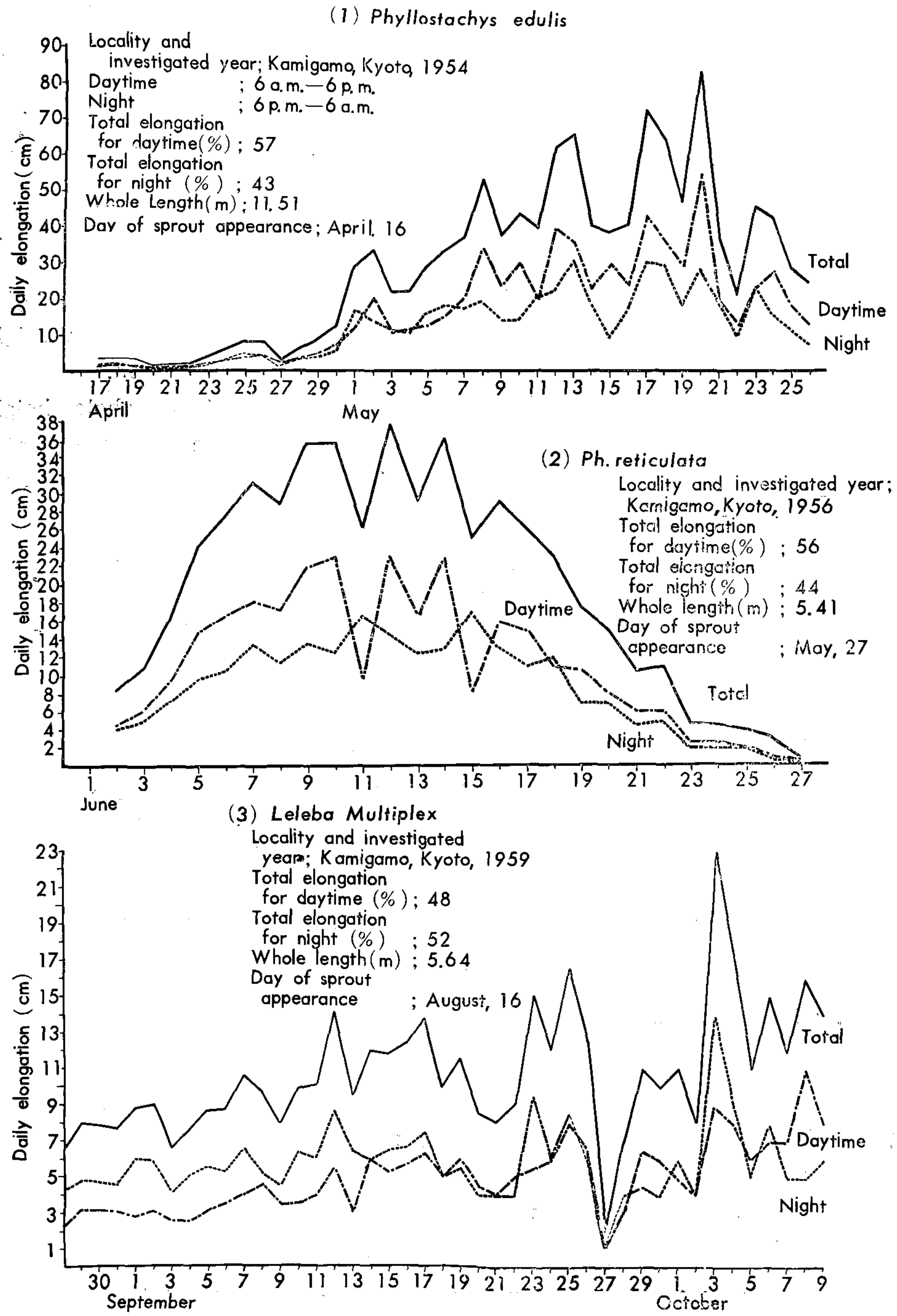
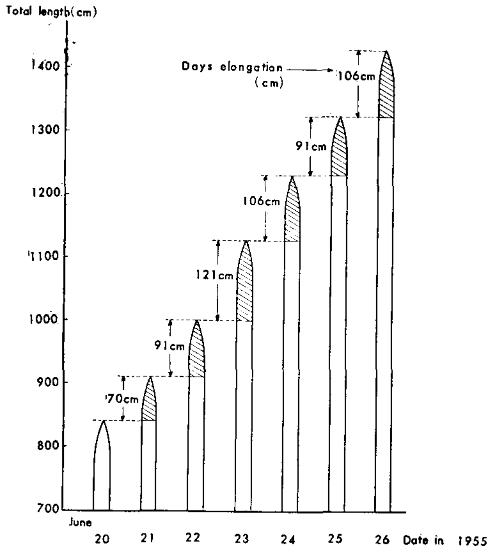


Fig. 4. Daily elongation of sprout of *Ph. reticulata* in the most vigorous growing period. This culm attains 12 cm in diameter at eye height



Regarding fertilizing practices, it is important to know the period of most vigorous growth. In *Phyllostachys*, the period is known by the following indications;

i) When the lowest branch starts growing.

ii) When the length of shoots reaches about 1/2 (*Ph. reticulata*) and about 2/3 (*Ph. edulis*) of the fully grown height of the culm.

The whole height of the culm is estimated by the diameter at eye height. In the case of *Ph. reticulata*, for instance, if the diameter at eye height is 5–8cm, then the fully grown height is calculated by $5\times200=1000$ cm, $8\times180\fallingdotseq1400$ cm (Table 35–(2)–(3)).

iii) When the period becomes about 2/3 in *Ph. edulis* and about 1/2 in *Ph. reticulata* of the entire growth period. (Table 4. 5.).

The maximum growth per day is small in *Leleba* species, but they grow continuously over several months. 29 cm was recorded as a daily maximum growth for *Leleba* species in Kyoto, while 30 cm for *Dendrocalamus* in India.[10)]

e. Vigorous growing power of bamboo and supply of the nutrients

For the management of a bamboo grove, it is important to elucidate what gives the bamboo a vigorous growing power. In the genus *Phyllostachys*, the factors are thought to be as follows:

i) The supply of organic nutrients reserved in rhizomes, as indicated by the following data:

(1) The growth of sprouts was measured for some dozen days in the darkroom covered with black cloth, and it was found that they grow as well as under normal condition.

Photo. 8

A new culm of *Phyllostachys edulis* growing through a roof of galvanized iron (Kyoto).

Table 5. Maximum increment of a culm in length per day (24 hours)

(1)	(2)	(3) fully developed culm (matured culm)	(4)	(5)	(6) Maximum increment in length per day			(7) Maximum of internode length		(8)	(9)	(10)	(11)
Species	Date of sprout-appearance on the ground	Girth at eye height (cm)	Total length of culm (cm)	Elongating term (days)	(a) Max. length (cm)	(b) Height above the ground (cm)	(c) Elongating term (days)	(a) Max. length (cm)	(b) Height above the ground (cm)	6b/4 (%)	7b/4 (%)	6c/5 (%)	Year investigated
Ph. edulis	Apr. 3	20.3	767.8	58	52.4	624.3	46	16.7	430	81	56	79	1957
	May 1	15.9	851.5	42	66.5	436.5	31	32.3	330	51	38	74	1957
	Apr. 1	20.9	892.9	56	47.0	616.9	40	21.3	320	69	36	71	1956
	May 13	20.9	1031.4	34	87.0	720.4	25	39.0	620	69	60	73	1956
Ph. reticulata	May 22	6.2	464.4	41	29.5	261.9	20	17.9	162	56	34	48	1957
	June 28	6.6	487.2	26	43.5	247.2	12	21.0	180	51	37	47	1957
	May 27	4.6	544.0	53	34.0	250.4	21	17.6	172	46	32	40	1956
	June 20	4.7	358.3	28	26.0	149.9	13	16.7	115	42	32	47	1956

Remark: (6)-(c) term of elongation from appearance of sprouts to maximum elongation
Locality: Experimental Forest Station of Kyoto University, Kamigamo, Kyoto

(2) Nutrients reserved in rhizomes are greatly utilized during the growing period of sprouts.[11]

(3) Nutrients such as soluble nitrogen, invert sugar, phosphate, etc., reserved in the rhizomes of *Phyllostachys* species are largely consumed after the termination of the sprouts'appearance. (Fig. 6, 7. Table 31-A, B.). The starch reserved in rhizome of *Pleioblastus pubescens* is extremely little after the termination of the sprouts'appearance (Fig. 5).

Fig. 5. Seasonal variation of reserved starch content in culm and rhizome of *Pleieblastus pubescens* in Kamigamo Exprimental Station, 1956

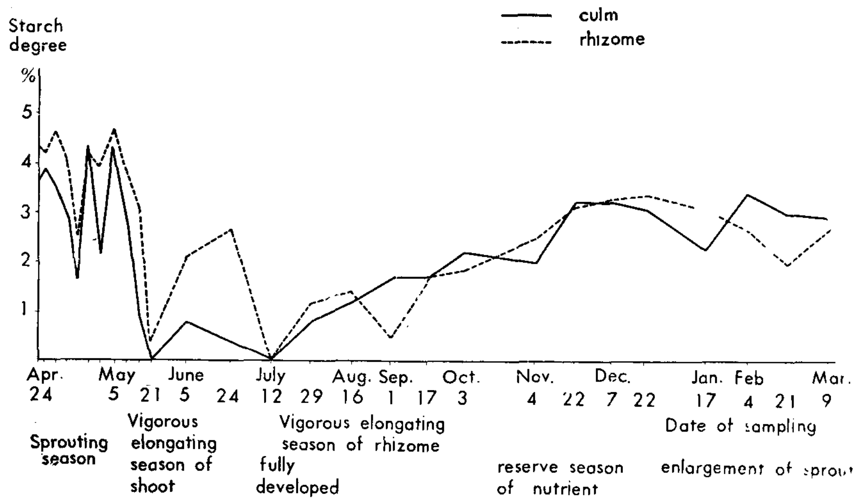


Fig. 6. Seasonal variation of water content in leaves and culms of *Phyllostachys reticulata* (5 th year old culm). Locality: Kamigamo Kyoto.

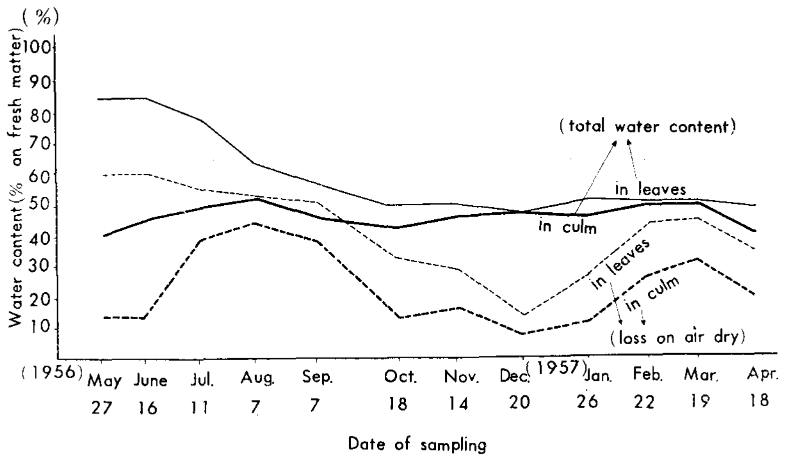
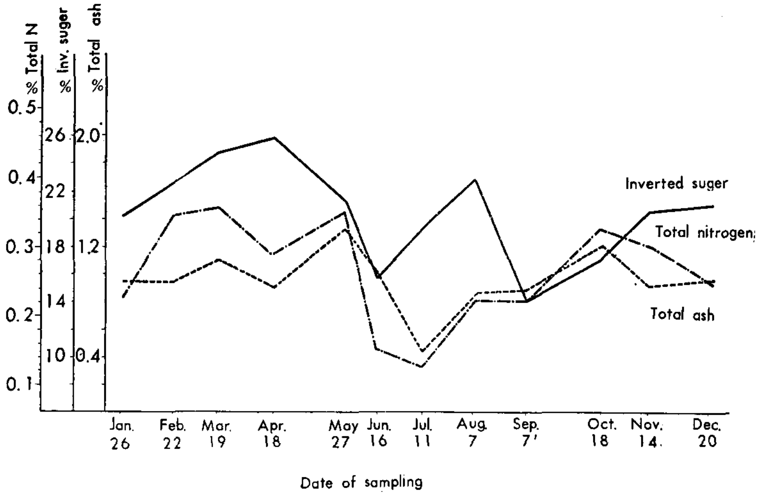


Fig. 7. Seasonal variation of invert sugar, nitrogen, and ash contents in the mid part of a 5-year-old culm of *Phyllostachys reticulata* in 1956, Mukomachi, Kyoto (% on air dry basis)



ii) The supply of assimilates from the mature bamboo: a radio isotope p^{32} injected into a mature culm was found to move actively through the rhizome into the sprouting shoots.[12][13]

iii) The supply of assimilates from sprouts themselves.

(1) When a sprout has grown to a certain extent, it produces nutrients by assimilation of itself.

(2) It was found that radio isotope p^{32} injected into the sprout does not move before the appearance of branches, but thereafter it is translocated to every part.[14]

(3) Reserve starch is not detected in sprouts under the ground, while it is found when it begins to grow on the ground.[15]

iv) The necessary amount of nutrients for the growth of sprout.

The author examined how many length of rhizome need for the growth of sprout. For instance, in *Pleioblastus pubescens,* a rhizome with more than four nodes is required for the full growth of a sprout.[15] In *Ph. reticulata,* longer than 7 meters are needed for the full growth of a sprout[16] (Table 6. 7). The fertilizing in early spring was remarkably effective on increasing the number of good sprouts. This is an indication that a lot of nutrient is required for their growth.

Table 6. The effect of rhizome cut at different length on the growth of culm in the *Phyllostachys edulis* grove

Newly developed culm \ Length of rhizome (m)		1	2	3	uncut (control)
Total length	(cm)	decay *	401	672	954
Girth (30 cm high above the ground)	(cm)	〃	17.1	20.9	20.0
Girth (140 cm high above the ground)	(cm)	〃	12.1	16.8	19.5
Internode length (140 cm high above the ground)	(cm)	〃	11.0	13.4	19.0
Total number of nodes		〃	43	51	52
Fresh weight of culm	(g)	〃	1820	2870	7445
Fresh weight of leaves and branches	(g)	〃	270	820	2900

Remark : Age of each rhizome is 2-3 years old. * Bamboo culms fell into decay.

Table 7. The content of reducing sugar and nitrogen compound in the cut rhizome in Table 6

Length of rhizome (m) \ Component	Reducing sugar (%)	Total-N (%)	Soluble-N (%)	Soluble-N / Total-N	Reducing sugar / Soluble-N
1	26.16	0.30	0.03	0.01	872.00
2	24.98	0.37	0.08	0.02	312.25
3	24.98	0.22	0.05	0.23	499.60
Uncut	23.32	0.49	0.19	0.39	122.73

Remark (1) These numerals show per air dry matter.
(2) The rhizomes are cut at different length in the soil, when their sprouts were elongated to 40 cm in length above the ground in the early part of April, 1957. Each rhizome has one sprout but no mother bamboo. They were excavated and investigated at the end of January 1958 after completion of their growth.

In the clump forming species of sympodial type which sprouts in summer, as the *Leleba* species, the movement of nutrients is different. In this type, as stated before, the buds on the basal underground part of one-year-old culms grow and immediately protrude out of the soil and develop into culms without forming long rhizomes. The nutrients for the growth of sprouts are mainly supplied by the assimilation of the mother bamboo. Therefore, their growth is slow, and it may take 3~4 months for the completion of their growth.

A-2. Growth of rhizome

Rhizome is very important as an organ in which nutrients are stored and through which the nutrients are translocated. It is also important for propagation. Therefore, the function of rhizome must be studied for the profitable management of a bamboo grove.

A-2-1. Bamboo species of monopodial type

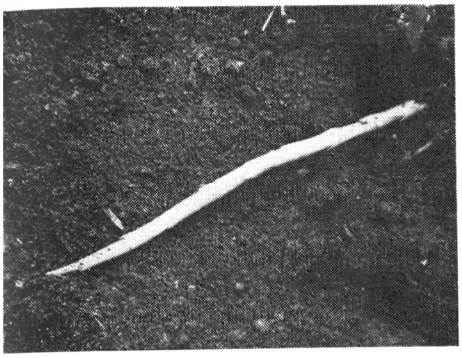


Photo. 9
The new rhizome of *Ph. edulis* grows 60 cm in length, in July 10, 1954.
at kamigamo, Kyoto

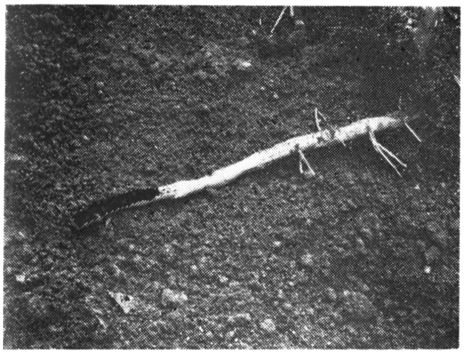


Photo. 10
Cutting at the position of 25 cm from the apex of the growing rhizome off in July 10, 1954.

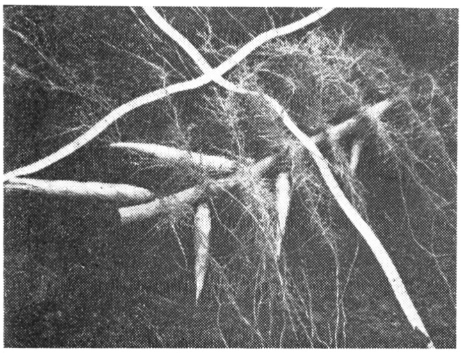


Photo. 11
The branches of rhizome grown abnormally after cutting of rhizome apex, in July 10, 1955.

a. Process of growing

A bud which will develop either into a culm or a rhizome is found at every node on a rhizome. A front bud of a one-year-old rhizome develops generally into a rhizome, but sometimes two or three buds near their apex develop to form rhizome branching (Fig. 9). Photo. 9~11 show the branching of rhizome after cutting of its apex.

Sometimes, in the species of monopodial type, when all mature bamboos are cut off entirely, some buds on a rhizome older than one year or on the basal part of a culm, develop into new rhizomes (Photo. 12). A similar phenomenon is found also when bamboo flowering occurs or lots of soil is deposited in a bamboo grove by floods.

Under the ground, the rhizomes grow wavily in all direction, and form a complex interwined network or chain form. They may arise sometimes above the ground, exposing about 10 cm in length. If the above ground portion of the young rhizome is removed, the yield of culms is reduced largely. Generally, the rhizomes are located within 1 m depth under the ground surface, but they grow deeper in fertile soil than in poor soil.

The growing period of a rhizome is about 5–6 months in *Phyllostachys* species. The growth of a new rhizome generally starts from

Photo. 12. Abnormal case of monopodial type after clear cutting of *Ph. reticulata* grove in Kyoto.
A slender new shoot has developed in a year after clear cutting of bamboos and the new rhizome has developed from the bud at its basal node in the second year.

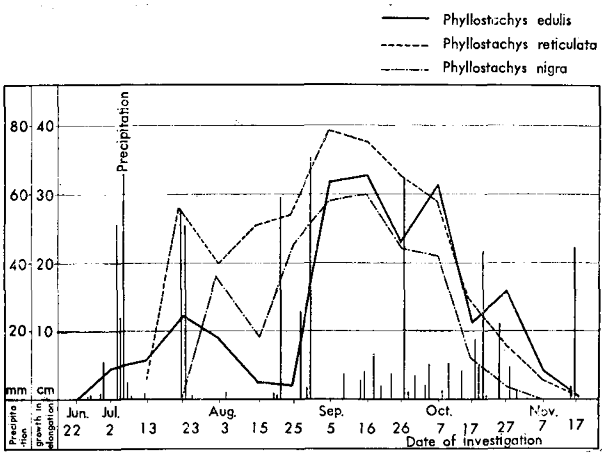
the middle to the end of June, after the elongation of culms has terminated. It becomes most vigorous from August to September and gradually slows down until it stops in the middle of November (Fig. 8). A rhizome developes to its full size within a year as in the case of culms. It is interesting that the culms and the rhizomes grow in alternation all through the year, namely, the rhizomes grow during summer and autumn when the temperature is relatively high, and the culms grow through winter to spring when the temperature is relatively low. The growing period of rhizomes seems to be longer than in the case of culms. The growing period of a culm, however, may be about 5–6 months if the period of its slow growth under the ground is taken into consideration.

In *Chinobambusa*, the growth of a new rhizome begins in early April and becomes most vigorous from July to August, and stops in October or November, when the sprouts of culm appear on the ground.

b. Seasonal growth

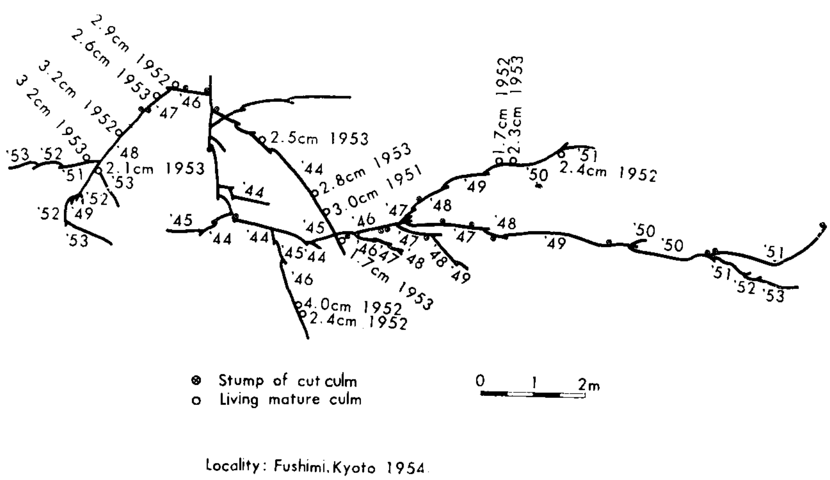
The weekly growth of rhizomes were measured for 7 years since 1952. The result measured in 1956 is as shown in Fig. 8.

Fig. 8. Relation between precipitation and seasonal elongation of rhizomes



Locality: KAMIGAMO EXPERIMENTAL FOREST STATION
KYOTO UNIVERSITY (1956)

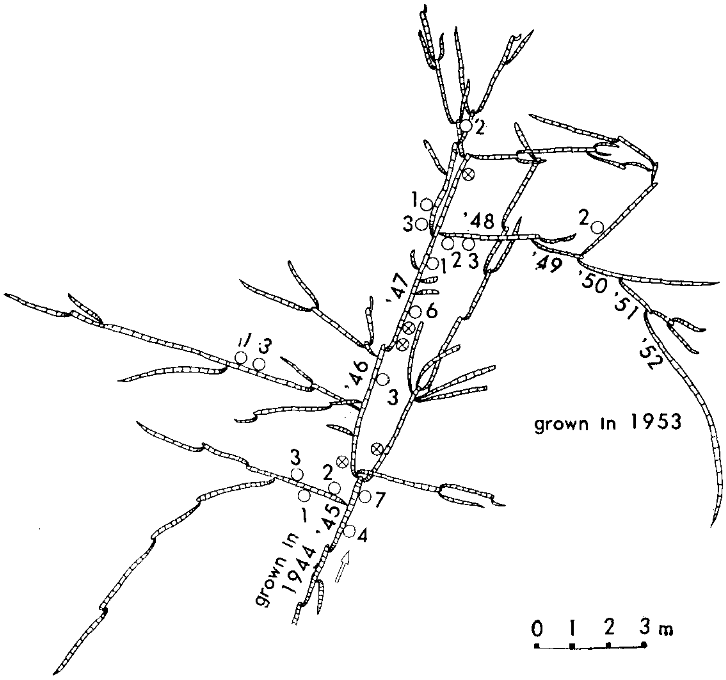
Fig. 9-a. A rhizome system excavated from the *Phyllostachys reticulata* grove showing annual development of rhizome segments and year of development of culms



Locality: Fushimi, Kyoto 1954

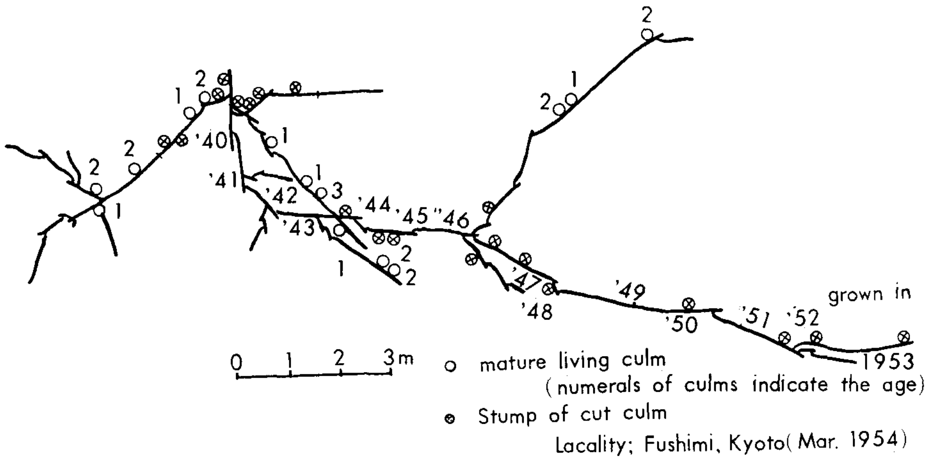
Fig. 9-b. A rhizome system of a well-cultured grove of *Phyllostachys reticulata*

Locality : Fushimi, Kyoto, 1955



○ mature living culm (numerals indicate the age)
⊗ Stump of cut culm

Fig. 9-c. A rhizome system excavated from an old grove of *Phyllostachys reticulata* in poor soil



Weekly growth of rhizomes varies according to the bamboo species, the soil and meteorological conditions. Their rhizome growth of *Ph. edulis* or *Ph. reticulata* is more affected by humidity, especially soil moisture, than temperature. Then it is decreased in the season of a low precipitation or in drought (Fig. 8).

Yearly growth of a rhizome is 1~3~6 meters (Fig. 9. 10). Growth of rhizomes depends on the amount of nutrients produced by assimilation of mother bamboos, but in the season when the rhizome grow most vigorously, starch and other nutrients reserved in the rhizomes, are also consumed, as understood from Fig. 5. These results were confirmed by the use of a radio isotope p.[32] [18] Furthermore *Phyllostachys* rhizomes produce many large culms in 2–6 year-old rhizomes. The details are explained in Part I, section B–1.

c. Growth of rhizome system[19]

The rhizomes grow every year and produce many culms from their buds, and then they live for about 10 years (*Phyllostachys* species). The total length of the newly grown rhizomes and that of the dead rhizomes every year are almost the same. Therefore the total length of the living rhizomes remains constantly in the grove.

Concerning the extension of a rhizome, for instance the density of rhizomes on the unit area and the way of their growth at every year should be considered. The former includes the rhizomes of various different systems mixed with one another as shown in Photo. 13 and Table 8, whereas the latter indicates one connected group of rhizomes belonging to a rhizome system as shown in Photo. 14, Fig. 9 and Tables 10, 11.

The researches on the extension of a rhizome system have been carried out by the excavation of them during 8 years from 1952 at 30 different sites.

First, the total length of the rhizomes in 9 square meter quadrate is given in the following Table 8.

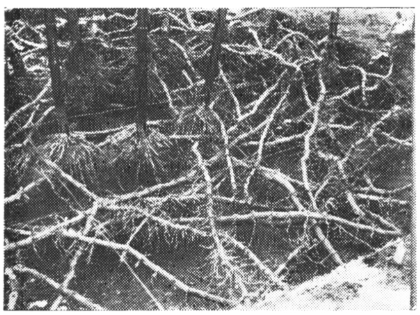


Photo. 13.
A network mixed with different rhizome systems of *Phyllostachys reticulata* grove at Mukomachi, Kyoto

Photo. 14. Excavating a rhizome system of *Phyllostachys reticulata* grove after clear cutting of the culms. in Nagaoka, Kyoto, 1955 (Man on left is the author)

Table 8-(a). The average length, diameter and fresh weight of rhizomes in 9 square meter of *Phyllostachys reticulata* grove

Locality: Mukomachi, Otokuni, Kyoto. 1955.
investigated area: 3×3m ($9m^2$)

Soil	Rhizomes					Culms	
	Length			Fresh weight (excluding roots)	Diameter of internode	Number	Average diameter at eye height
	Living (m)	Dead (m)	Total (m)	(kg)	(cm)		(cm)
Good soil	35	44	79	34	2.6	18	7.3
Poor soil	50	47	97	31	2.1	39	3.5

Table 8-(b). Average internode length and diameter at the middle position of the internode of the rhizome

Species / Soil	*Ph. reticulata*		*Ph. edulis*		*Ph. nigra*	
	Length (cm)	Diameter (cm)	Length (cm)	Diameter (cm)	Length (cm)	Diameter (cm)
Good soil	4.8	2.4	5.3	2.6	3.3	1.1
Poor soil	3.2	1.7	3.3	1.7	2.5	0.9

The total length and fresh weight of living rhizomes in 0. 1 ha. is shown in Table 9.

Table 9. Total length and fresh weight of living rhizomes per 0.1 ha. of bamboo groves

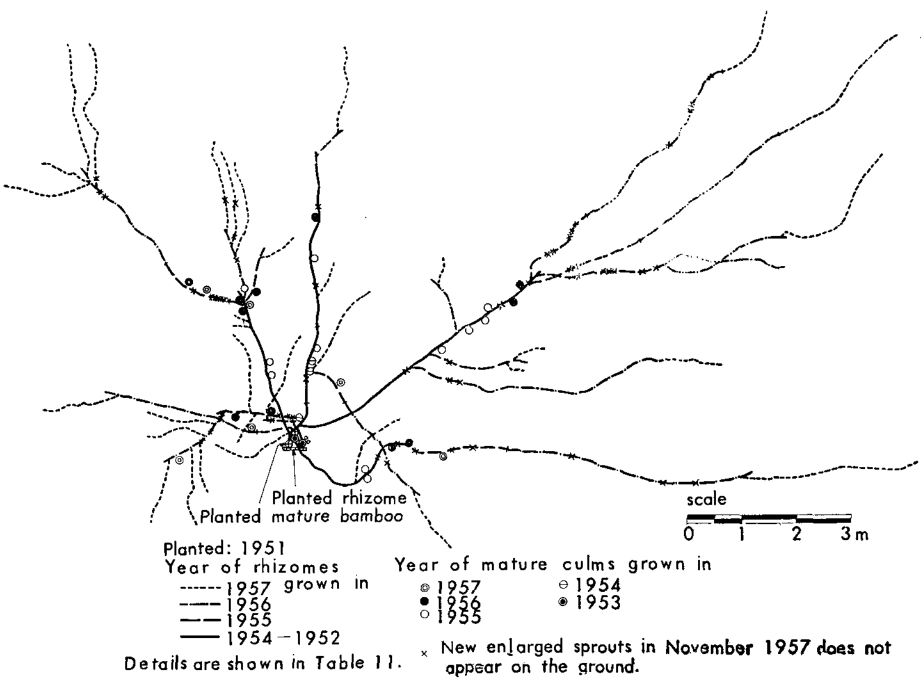
Species	Total length (m)	Fresh weight (kg)
Phyllostachys edulis	2, 500—11, 290	1, 500—6, 700
Phyllostachys reticulata	6, 300—18, 740	2, 000—8, 500
Phyllostachys nigra	14, 130—18, 060	1, 000—3, 000
Pleioblastus pubescens	47, 240—57, 920	400—1, 500

All rhizomes within a quadrate were dug up and then measured and weighed. From the above description, it may be understood how many rhizomes form a network in the soil of a bamboo grove.

Next, the extension of a rhizome system is shown in Table 10, and Fig. 9, a, b, c.

Fig. 10. An annual extension of a rhizome system of *Phyllostachys reticulata* developed during 6 years after transplanting of a mother bamboo

Kamigamo, Kyoto, in November 1957



The position of each culm is indicated by symbols which designate the year in which the culm appeared.

Table 10. *Measurements of rhizomes and culms during 10 years belong to a rhizome system in the old grove of* ***Ph. edulis*** *and* ***Ph. reticulata*** *in 1954*

Species	*Ph. edulis*		*Ph. reticulata*			
Locality	Fushimi		Saga		Fushimi	
Month excavated	Feb.	Mar.	June	June	Mar.	May
Quality of grove	Poor	Average	Poor	Poor	Poor	Good
RHIZOMES (lived) — Elongation per year — Minimum (m)	0.55	0.15	0.30	0.22	0.10	0.15
RHIZOMES (lived) — Elongation per year — Maximum (m)	3.65	5.28	3.30	2.45	3.11	4.97
RHIZOMES (lived) — Elongation per year — Average (m)	1.68	1.84	1.41	1.27	0.94	1.55
RHIZOMES (lived) — Total length (m)	51.2	55.1	24.0	24.0	41.2	148.8
RHIZOMES (lived) — Total area occupied (m²)	62	48	10	13	48	118
RHIZOMES (lived) — Number of branches	18	25	14	20	54	95
RHIZOMES (lived) — Average diameter (cm)	2.1	2.2	1.9	1.9	1.2	1.9
RHIZOMES (lived) — Average length of internodes (cm)	3.9	3.8	4.4	3.6	3.8	4.5
RHIZOMES (lived) — Depth (underground) — Minimum (cm)	5	7	6	8	12	5
RHIZOMES (lived) — Depth (underground) — Maximum (cm)	40	27	27	35	34	55
RHIZOMES (lived) — Depth (underground) — Average (cm)	17	20	16	19	16	25
CULMS — Number — Stump of cut culms	0	1	0	3	14	4
CULMS — Number — Standing mature culms	7	6	2	3	14	16
CULMS — Diameter — Minimum (cm)	3.7	7.1	4.8	4.4	1.9	5.4
CULMS — Diameter — Maximum (cm)	6.9	9.5	5.6	5.7	5.0	7.2

Remark; These groves were managed extensively.

Table 11. *The extension of rhizomes and the culms developed from them during several years after the transplanting a mother bamboo shoot in each species*

Species	No. of years after the transplanting of a mother bamboo	Rhizomes after transplanting of a mother bamboo shoot: Number of rhizome branches	Diameter of internode (cm)	Total length (m)	Maximum elongated length per branch in a year (m)	Newly grown culms: Number	Diameter at eye height (cm)	Total area occupied by: Rhizomes (m²)	Mature culms (m²)
Ph. edulis	1-4 (1949-1952)	23	1.2-2.0	28.40	1.93	10	1.2-4.5	19	2
Ph. reticulata	1-2 (1953)	2	0.8	2.72	1.56			4	
	2-3 (1954)	5	1.4	11.64	3.58	3	1.0	30	1
	3-4 (1955)	13	1.5	18.56	2.83	10	1.3	54	20
	4-5 (1956)	12	1.6	29.61	4.94	10	1.3	84	28
	5-6 (1957)	33	1.8	42.21	3.84	7	1.6	170	33
	total (1-6)	65		104.74		30			

Remark; The soil quality of the bamboo grove is poor. This data is as shown in Fig. 10
Locality; Expeirmental Forest Station of Kyoto University, Kamigamo, Kitaku. Kyoto.
Year investigated; 1957 in *Ph. reitculata* grove, 1953 in *Ph. edulis* grove.

Table 10 and Fig. 9 show the annual extension of a rhizome system in an old bamboo grove. Namely, the total area occupied by the annual extension (for 10 years) of a rhizome system in an old grove of the *Phyllostachys* is 200–400 m^2 in a good grove (Fig. 9, b) and 20–100 m^2 in a poor grove (Fig. 9, c).

Table 11 and Fig. 10 show one way of annual extension of a rhizome system at an area free of competition with other rhizome systems in the grove after the transplanting of a shoot. Namely, one shoot with rhizome transplanted from which extend, new rhizomes by branching in all direction every year. Although this soil quality was poor, the rhizomes and their branches spread over 170 m^2 and 30 culms developed from them in 6 years.

Judging from Table 11, in order to establish a new bamboo grove in a short period, it is desirable to plant about 300 good shoots with rhizome per 1 ha.

Determination of the rhizome age;

A one-year-old rhizome is partly covered with sheaths and its roots has few fibrous roots at the nodes. In determinating the age of over two-year-old rhizomes, it is possible to distinguish them from all other rhizomes excavated, belonging to one system. But the correct age of a single part of a rhizome can neither be distingushed nor determined, although one may be able to decide whether it is young or old. Namely, the young rhizomes are yellowish and have vigorous buds; furthermore, they bear roots with many fibrous roots at each node. The rhizome of over about 6 years becomes brownish and its nodes have but few vigorous buds and fibrous roots.

A-2-2. Bamboo species of sympodial type

a. Growth of clump forming species

Bamboo species of this type have very short rhizomes, which look like a part of a culm. The rhizome first grows horizontally within a very short distance, then turns at a right angle and grows upwards out of the ground, thus forming a clump.

Leleba species in Japan and many species in tropical regions belong to this type (photo. 21).

b. Growth of single culm forming species

Being different from *Phyllostachys* species, the rhizomes of the *Melocanna* species have short internodes, and have no buds, Their apices protrude out of the soil and grow into culms.

In cooperation with two assistants in India (Cachar, Assam) in 1959, the present author found that each of the several buds on the basal part of the culm under the ground enlarged from the end of autumn in the previous year, and grew into rhizomes in the spring. One of the rhizomes protrudes out of the soil and develop into a culm from May to July, while the remaining rhizomes cease growing. The annual growth of this rhizome (the length of the rhizome inserted between culms) is 1–2 m long (Photo. 15).

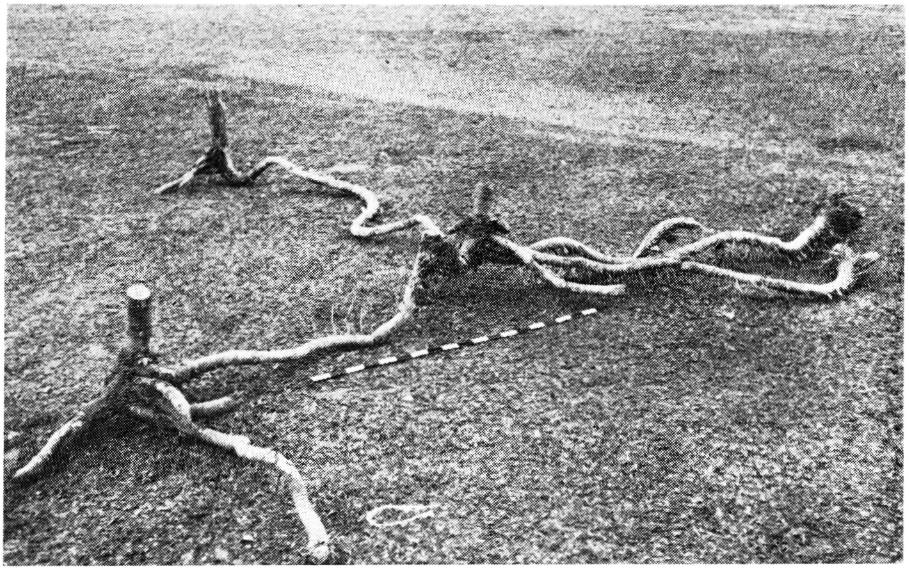


Photo. 15. A rhizome system *Melocanna bambusoides* in Assam, India.
Photo: March 1959.
Scale is marked at 20 cm intervals.

Photo. 16. A natural grove of *Melocanna bambusoides* in Assam, India
Photo: March, 1959.

A-3. Growth of roots of culm and rhizome

a. Number of roots

The number of roots of a culm varies according to the size and the age of the culm and the condition of the soil. The following table shows some of the results of measurements.

Table 12. Number, length and weight of roots developed on the basal part of a culm of *phyllostachys edulis* and *ph. reticulata*

Species	Horizontal extension of roots (cm)	Roots of a culm		Fresh weight of roots of a culm (g)	Culm	
		Average length (cm)	Number		Diameter at eye height (cm)	Age (years)
Ph. edulis	120～180	71	1, 436	5, 850	11	2
	90～120	81	350	2, 510	7	3
	90～110	59	754	3, 760	6	5
Ph. reticulata	70～ 90	57	444	1, 860	7	2
	55～ 65	57	310	600	5	3
	25～ 46	40	275	196	3	4

Locality; Kamigamo and Fushimi, Kyoto (1954)

The number of roots of a culm varies from 275 to 1436 (Table 12). The larger culms generally have more roots.

When a culm becomes older than 6–7 years, its fibrous roots or root hairs, which are the organs of nutrient absorption, markedly reduce in number. Then productive power of the culm deteriorates.

Roots grown at each node of rhizome are about 70 cm in length, and the number of roots per node varies from 7 to 25, which is quite less than those of the culm (Photo. 18).

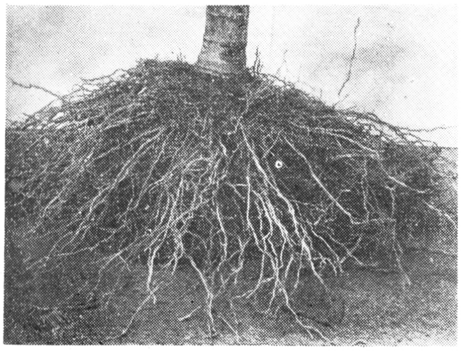


Photo. 17. Vigorous root system of younger culm of *phyllostachys edulis*

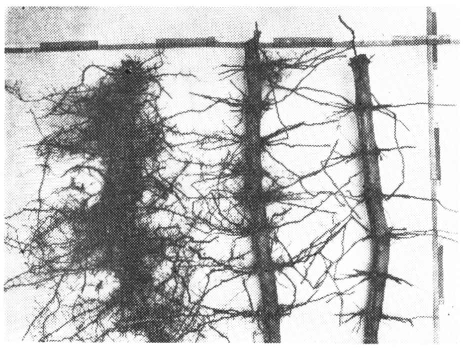


Photo. 18. Growth of rootlets on rhizomes at different ages.
Left : 1–3 years old. Right : over 10 years old.
Center : 4–9 years old.

Fig. 11 (1). *Root system of a culm of* ***ph. reticulata***

Diameter of root; 3.63mm

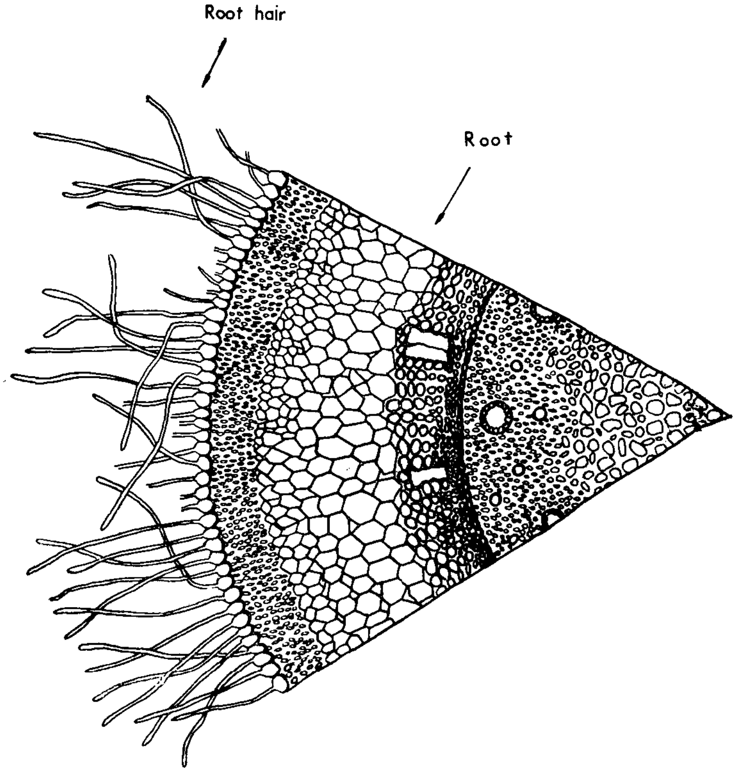
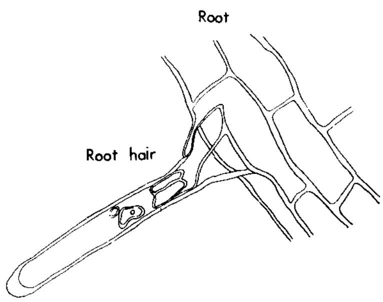


Fig. 11 (2). Enlarged root hair of a culm of ***ph. reticulata***

Diameter of root-hair; 0.01mm



b. Growth of roots

Many new roots are generally growing from the basal part of a sprout (underground) (Photo. 3, 4). These roots continue growing gradually and complete the their growth within a year. Elongation of their roots are 40–100 cm and thereafter neither grow nor thicken in diameter.

Note or References:

1) In northern India, sprouts of the *Bambusa* species and *Dendrocalamus* species appear in June-July, while in southern India it is in September-October after the rainy season.
2) Y. Shigematsu: Jour. Jap. Forest. Soc. No. 23, Vol. 3, 1951.
3) Unpublished.
4) The growing point is located at each internede. In relation to this, prof, K. Ueda confirmed that the cutting of the apex of a sprout does not stop the elongation of the remnant portion.
5) Jour. Jap. Forest. Soc. No. 23, Vol. 3, 1951.
6) Unpublished.
7) Ann. Botanical Garden. Peradeniya. (1906).
8) Y. SHIGEMATSU. Jour. Jap. Forest. Sec. No, 23, Vol. 3, 3,1951
9) Unpublished.
10) Indian Forest. Vol. 11, No. 4, 1940.
11) Transaction. Jap. Forest.Soc. No. 68, Apr., 1958.
12) Jour. Jap. Forest. Soc. No. 67, Apr., 1957.
13) Transaction. KANSAI Branch, Jap. Forest. Soc. Oct., 1959.
14) Ibid.
15) Ibid.
16) Transaction. Jap. Forest. Soc. Apr., 1958,
17) Transaction. Jap. Forest. Soc. No. 8, Oct., 1958. No. 9, Oct,. 1959.
18) Transaction. KANSAI Branch. Jap. Forest. Soc. No. 6, Non., 1956.
19) In such research work, digging those rhizomes out of the soil, is troublesome and costly.

B. Propagation (asexual propagation)

B-1. Bamboo species of monopodial type

Among the species, in which the buds on the nodes of a rhizome develop into new culms, *Ph. reticulata* and *Ph. edulis* will be mentioned first.

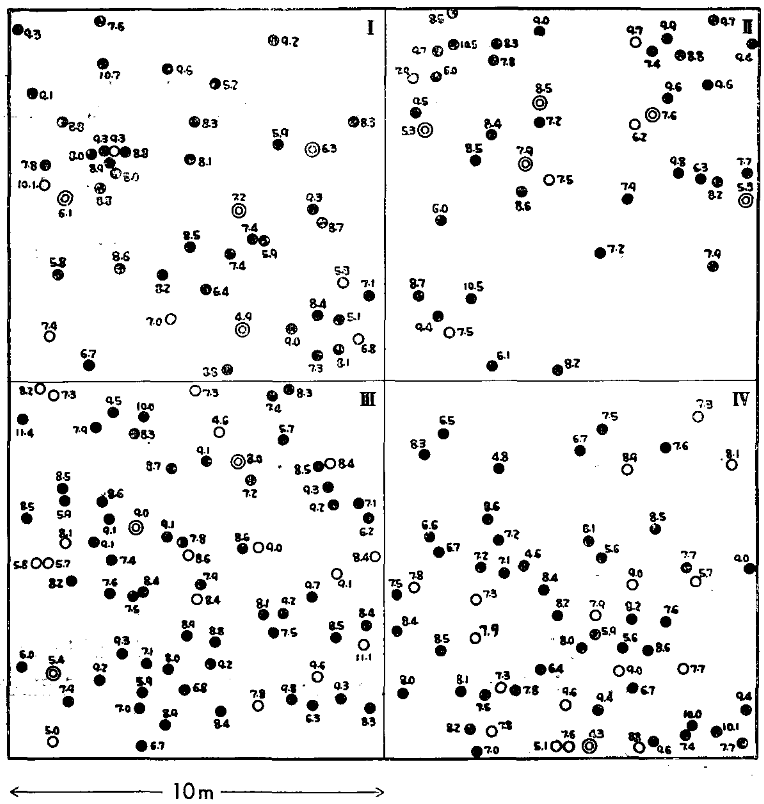
a. Number of newly grown culms annually

A bamboo grove produces a great number of new culms asexually every year, even though thinning (harvest) of culms is repeated.

The genus *Phyllostachys* regenerates new rhizomes and new culms even when it reaches the stage of flowering; thus propagation goes on permanently.

The number of new culms per ha. produced every year is 1,000–5,000 in *Ph. reticulata* grove and 500–3,000 in *Ph. edulis* grove. The proportion of new culms produced every year to that of mature bamboos[3] (over 2-year-old bamboo) is 20—30% in the grove of *Ph. reticulata* and 10—20% in the grove of *Ph. edulis.* The number of new culms produced every year per unit area varies according to the species, size, age, number of mother bamboos, soil and climate conditions or the management of a grove. An example is shown in Table 57 and Fig. 12. The number of newly grown culms is less in the species with large-size culms than in those with smaller culms. This trend is seen on the species, namely the number of newly grown culms every year is less in a better grove than in a poor one. But as for the production of volume (*soku*) of new culms, the grove of large-size culms will be produced more than that of small-size culms.

Fig. 12. Location of culms, their size, and year of appearance in the good grove of *phyllostachys reticulata*



● 3 to 6 year old culms grown before 1954. ◎ 2 year old culms grown in 1955
○ 1 year old culms grown in 1956. Figures are diameter of culms at eye height (in cm).
Locality; Saga, Kyoto (1956). Details are shown in Table 13.

Photo. 19. Emergence of bamboo sprouts in *ph. edulis* grove.

Bamboo sprouts were beginning to appear on the ground in early April 1960(off year) in Kyoto.

It is possible to increase the number and size of new culms by fertilizing. In bamboo groves which are not well managed, new culms decrease in number and their quality becomes inferior. The production of new culms fluctuates every year, generally speaking, good and poor production occur in alternate years. In the on year, the larger number of culms of better quality are produced, while, in the off year, smaller number and poorer quality of culms are produced (Tables 16 and 34).

Table 13. Relation of number and size of culms to each age in a grove of *ph. reticulata*

Plot No.	Number of culms				Proportion of total number (%)			Average size of culms (D.E.H.)		
	1 year old	2 years old	3-6 years old	Total	1 year old	2 years old	3-6 years old	1 year old	2 years old	3-6 years old
1	5	4	38	47	10.6	8.5	80.9	7.7	6.1	8.0
2	5	5	32	42	11.9	11.9	76.2	7.4	6.9	8.4
3	18	3	55	76	23.7	3.9	72.4	7.8	7.5	8.2
4	17	1	44	62	27.4	1.6	71.0	7.8	4.3	7.7
Aver-age	11	3	43	57	19.8	5.7	74.4	7.7	6.6	8.1

1) **Each plot area is 100m²; this study was carried out in a private grove at Matsuo, Kyoto on Nov. 1956 before harvesting,**

Fig. 13-a. Relation between the age of rhizomes and the number of unemergence sprouts in the *phyllostachys edulis* grove on 5-rhizome systems.
Locality; Fushimi, Kyoto (April, 1954~57)

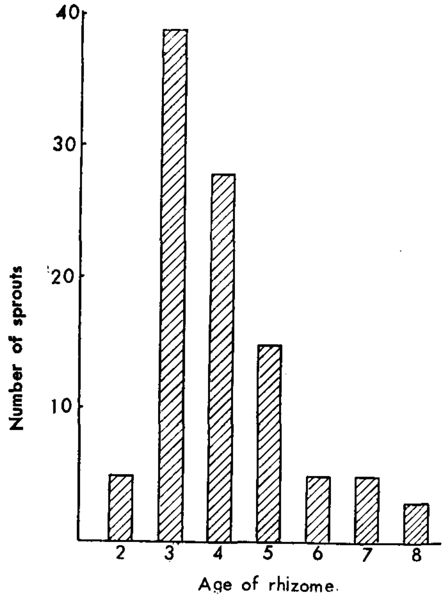
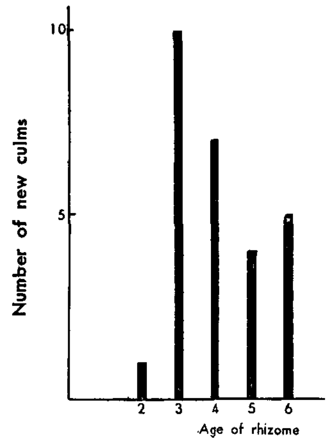


Fig. 13-b. Relation between the age of the rhizomes and the number of their new culms in the *phyllostachy edulis* grove on the 6-rhizome systems.
Investigated; 1954~57 in Kyoto.



b. Relation between the age of rhizomes and the number of newly developed culms

A rhizome bears a single bud on each node. Some of these buds develop into new culms. Judging from the investigation on the rhizome of *Phyllostachys* excavated, it was found that the buds on one year old rhizomes usually did not develop into culms, because these buds are not yet matured.

The 2-6-year-old rhizomes, especially the 3-5-year-old, are vigorous and produce the largest number of new culms of good quality[2] (Fig. 13 a, b and Tables 14 and 15).

But even if the age of a rhizome is 2–6 years old, only one or two out of ten buds can sprout and develop into culm, in the same year. But it is not well known which bud develops into a culm.[2]

The older rhizomes produce fewer new culms; for instance, a sprout seldom develops from over 10-year-old rhizomes, because such rhizomes have very few buds, and are not vigorous (Photo. 27 and Table 32).

c. Undeveloped sprouts (So called "Tomari-takenoko" in Japanese)

Some sprouts stop growing less than 40 cm in height and do not develop into mature culms. They are called "Tomari-takenoko" in Japanese. Investigations were conducted for four years at those bamboo groves in the vicinity of Kyoto where the unexpectedly larger number of such cases oc-

Table 14. Relation between the age of rhizomes and the number of sprouts in a rhizome system

Number of sprouts by each age of rhizome

	Phyllostachys reticulata grove				*Phyllostachys edulis* grove	
	Good grove		Poor grove		Ordinary grove	
Age of rhizome	Number of sprouts	%	Number of sprouts	%	Number of sprouts	%
2 years old					2	6.7
3 years old	2	20	4	27	13	43.3
4 years old	4	40			5	16.7
5 years old	1	10	3	20	7	23.3
6 years old	1	10	3	20	1	3.3
7 years old			4	27	1	3.3
8 years old			1	6	1	3.3
9 years old	2	20				
Total	10	100	15	100	30	100.00
Total length of rhizomes (m)	148		41		111	
Number of mature living bamboos	16		14		3	
Number of sprouts per one mature bamboo	0.6		1		10	
Object of production	culms		culms		edible sprouts	

Investigated; 1954–1955
Locality; Mukomachi and Nagaoka, Kyoto

Table 15. Number of rhizome-buds, sprouts by age of rhizome at a rihzome system

(1) *Phyllostachys reticulata* (good grove)

Rhizomes		Number of rhizome-buds, sprouts					(4)/(3)
Age (year) (1)	Total length (m) (2)	Total (3)	Buds (4)	Unemergence sprouts (5)	Sprouts grown into culms (mature culms) (6)	Dead buds (7)	%
2	23.12	473	454	0	0	19	96
3	20.26	430	355	2	0	73	83
4	20.80	473	360	4	0	109	76
5	28.44	569	379	1	3	186	67
6	19.38	403	226	1	1	175	56
7	21.09	338	123	0	8	207	36
8	5.16	82	22	0	4	56	27
9	6.60	99	7	2	3	87	7
Total	144.85	2867	1926	10	19	912	

Locality: Mukomachi, Kyoto, Mar. 1954

(2) *Phyllostachys reticulata* (poor grove)

Rhizomes		Number of rhizome-buds, sprouts					(4)/(3)	(5)/(3)	(6)/(3)
Age (year) (1)	Total length (m) (2)	Total (3)	Buds (4)	Unemergence sprouts (5)	Sprouts grown into culms (mature culms) (6)	Dead buds (7)	%	%	%
2	3.32	96	94	0	1	1	98	0	1
3	2.19	91	71	4	0	16	78	4	0
4	4.91	115	54	0	3	58	47	0	3
5	5.22	114	79	3	4	28	55	2	3
6	4.83	158	38	3	1	116	24	2	1
7	5.08	133	33	4	3	93	25	3	2
8	4.61	139	6	1	5	127	4	1	4
9	4.25	109	9	0	4	96	8	0	4
10	2.26	73	8	0	2	63	1	0	3
11	4.55	140	45	0	3	92	32	0	2
Total	41.22	1,168	437	15	26	690			

Locaity: Mukomachi, Kyoto (Mar. 1953)

Note ; (4) : Some of buds grow into sprouts in the future.

(5) : Unemergence sprouts may appear above the ground in the same year.

(6) : Culms are over 1 year old.

(3) *Phyllostachys edulis* grove used as edible sprouts

Rhizomes		Number of rhizome-buds, sprouts					(4)/(3)	(5)/(3)	(6)/(3)
Age (year) (1)	Total length (m) (2)	Total (3)	Buds (4)	Unemergence sprouts (5)	Sprouts grown into culms (mature culms) (6)	Dead buds (7)	%	%	%
2	25.51	566	553	2	0	11	98	0	0
3	23.84	475	402	13	10	50	85	3	2
4	15.93	350	220	5	5	120	63	1	1
5	13.32	288	156	7	4	121	54	2	1
6	9.86	198	51	1	2	144	26	1	1
7	7.31	171	23	1	1	146	13	1	1
8	4.77	86	3	1	0	82	3	1	0
9	3.52	70	0	0	0	70	0	0	0
10	4.51	89	0	0	0	89	0	0	0
Total	108.57	2,293	1,408	30	22	833			

Locality: Nagaoka, Kyoto (Apr. 1954)

cured. The preliminary results are as follows. The number of undeveloped sprouts was 90–360 (60–80%) per 0.1 ha in the grove of *Ph. edulis*, and 90–170(30–50%) in that of *Ph. reticulata*. The proportion of that of undeveloped sprouts to the number of emerged sprouts became higher at the late season (Table 16, Fig. 14 and Photo. 20).

Photo. 20

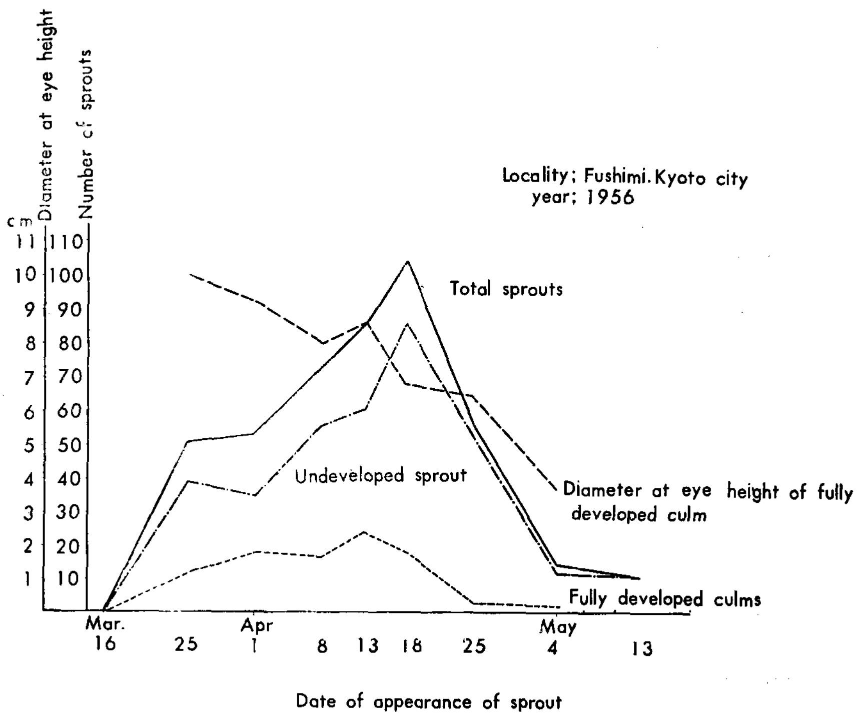
View of a grove of *Phyllostachys edulis* which consists of newly whitish immature culms, the mature culms in the background and the undeveloped sprouts with sheaths in the foreground.

Table 16. Specification for number of sprouts in a bamboo grove

Number of total sprouts, fully developed culms and undeveloped sprouts. (per 10 a.)

Species (grove)	Site grade (soil condition)	Fertilizing treatment	Total number of sprouts (1)	Developed sprouts (matured culms) (2)		Number of undeveloped sprouts (3)	(3)/(1) (%) (4)	Standing Bamboos before harvesting (5)		Year investi-gated (6)	On or off year (7)	Locality
				Number	Diameter at eye height (cm)			Number	Diameter at eye height (cm)			
Ph. edulis	Ordinary	Non fertilizing	526	166	8.4	360	68.4	453	8.3	1953	on year	Fushimi
			136	37	7.2	99	72.8	619	8.7	1954	off 〃	
			446	94	9.3	352	78.9	617	9.0	1955	on 〃	
			378	120	9.2	258	68.3	575	9·3	1957	on 〃	
		Fertilizing	640	180	8.4	460	71.9	490	10.4	1957	on 〃	
	Good	Fertilizing (few in number)	224	131	12.6	93	41.5	526	13.4	1955	off 〃	Nagaoka
			236	74	13.1	162	68.6	562	13.2	1957	off 〃	
Ph. reticulata	Ordinary	Non fertilizing	396	232	3.7	164	41.2	694	4.9	1956		Saga
		Non fertilizing	544	371	3.0	173	31.8	830	4.3	1956		Oharano
	Poor	Non fertilizing	450	360	3.8	90	20.0	1630	3.7	1957		
		Fertilizing	1380	580	4.6	720	55.4	1070	4.9	1957		

Fig. 14. Relation between the date of appearing of sprouts and the number of their total sprouts, undeveloped sprouts, fully developed culms and diameter of their culms in the *Phyllostachys edulis* grove



Approximately 90% of undeveloped sprouts were less than 30 cm in height as shown in Table 17.

Table 17. Relation between the number of undeveloped sprouts and their height in the *Ph. edulis* grove

Height classes	Bellow ~ 10 cm	11 cm ~ 20 cm	21 cm ~ 30 cm	31 cm ~ 40 cm	41 cm ~ over	Total	Average
Number of undeveloped sprouts	178	98	60	25	21	382	18. 1
%	46. 6	25. 7	15. 7	6. 5	5. 5	100	

Locality: Fushimi, Kyoto

As to the causes for the occurrence of undeveloped sprouts, the want of nutrition may be considered first. It is natural that nutrients may be lacking for the growth of many sprouts produced during a short period. Fertilizing increases the number of sprouts and decrease the rate of undeveloped sprouts. The second possible cause may be insect attacks.

But in some places, only a few sprouts stop developing because of these attacks.

In any case, it is advisable to take out those sprouts for food as soon as possible. It is also profitable to thin out by selecting the late sprouts, using them for food. Because, many of the sprouts that develop later than the vigorous sprouting period generally will develop into poor bamboos any way.

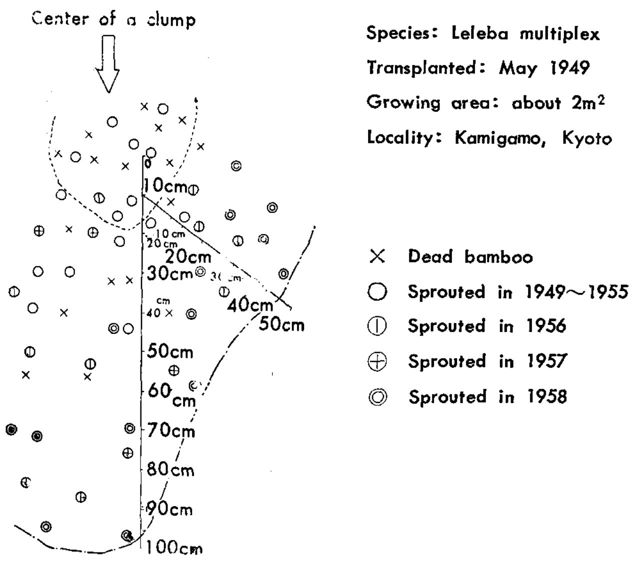
B-2. Bamboo species of sympodial type

B-2-1. Clump forming species

Bamboo species that form clumps mainly grow in the tropical regions. In Japan, *L. multiplex*, which belongs to the genus *Leleba* that forms clump is found, but its culm size is small. Each of the nodes of the basal part of the culm in the soil bears one large bud.

This basal part of the culm is considered as a rhizome. Among the buds on the basal part of one-year-old culm, one or two vigorous ones[4] situated on the outer side protrude immediately out of the ground to grow into culms in summer (Fig. 15, Photo. 21). Therefore, culms of the clump grow densely. Since buds of young culms develop into new culms, old culms

Fig. 15. An extension of the new culms grown every year after transplantation



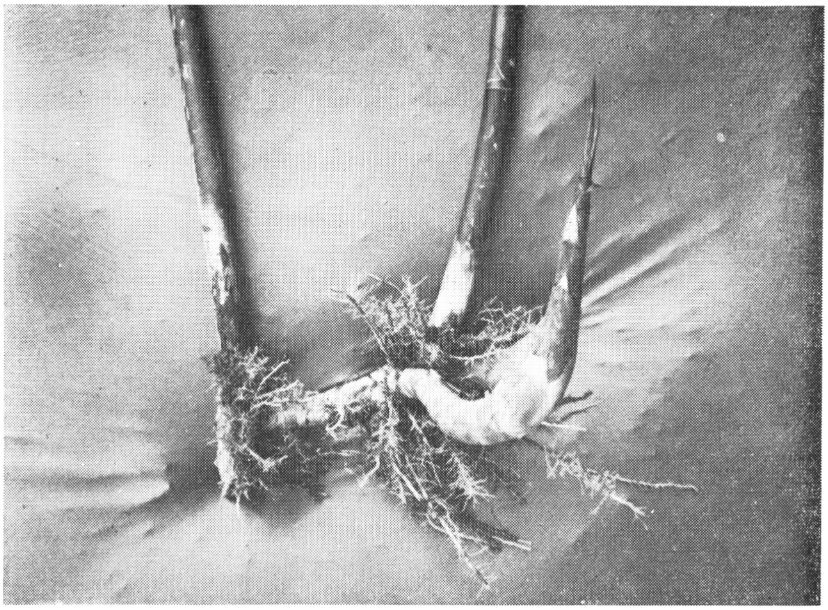


Photo. 21. Development of sprout of *Leleba multiplex*

Left : 2 year old culm.
Center: 1 year old culm.
Right : new sprout in 1959.
Lacality : Kamigamo, Kyoto.

tend to concentrated in the central part of the stock and new culms spread around in the periphery to form a clump. After several decades, many bamboos of the clump flower and die. The regeneration thereafter will be described in Section 3 of Part I.

The number of new culms that develop from a clump varies by species, soil and climate conditions, method of thinning, size of a clump-culm, and overhead cover etc. In *Dendrocalamus strictus* in India,[4] (1) one of the most important climate factors influencing the production of new culms is the rainfall and its seasonal distribution. If the monsoon comes in the normal time, and the rain fall is well distributed and normal in amount, the production of new culms is good, but if the monsoon comes at the abnormal time, or if there is a break after the first heavy showers, the production of new culms is unfavourably affected. (2). The method of thinning has a direct bearing on new culm production, whereas clear cutting may completely stop the production of well developed culms for a year or more, a suitable thinning may result in enhanced production. (3). Although bigger clumps produce more new culms, the ratio between new and old culms fall off with the extension of the clump. (4). Clumps growing in the open produce culms of much better quality and quantity than the clumps growing under heavy shade.

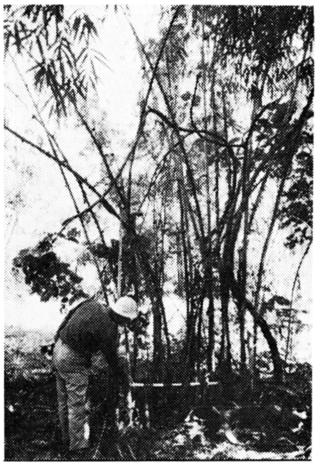


Photo. 22 (Left)
A clump of *Dendrocalamus strictus*

Balaghat, Madhya pradish, India. Feb. 1959.
Scale is marked at 20 cm intervals.

Photo. 23 (Right)
A clump of *Bambusa arundinacea*

Mettur, Madras, India. March 1959.

The results of the investigation on the number of newly grown culms every year in *Leleba multiplex* grove in Kyoto are shown in Table 18 and Fig. 15.

Table 18. New culms produced every year in a clump after transplantating

Species: *Leleba multiplex*
Transplanted: May 1949

Growing area: about 2 m^2
Fresh weight of a culm: 530g on an averege

Sprouting year	Number of new culms	Total fresh weight of culms	Average diameter at 10 cm above ground
		kg	cm
1958	50	26.50	2.0
1957	45	23.85	2.0
1956	26	13.59	2.5
1955-49	103	54.59	1.6
Total	224	118.72	

Locality: Experimental Forest station of Kyoto University, Kyoto (Feb. 1959)

Results of the investigation on the number of new culms of bamboo species that grow in India will be described in Section 1, A-1 of Part II.

In the clump forming species, all sprouts do not fully develop and some of them stop also growing for various reasons. By the result of the investigation at the experimental site of Kyoto University, it was found that the number of these undeveloped sprouts was about 10–30% of the total number of sprouts as shown in Table 19. But in a grove under natural conditions, the number of sprouts developed from one culm usually is 1–2, and the number of undeveloped sprouts appear to be small.

The main causes of these undeveloped sprouts are the lack of nutrition and the damage of insects. Further, in India the apices of young shoots are often broken by monkeys or otherwise and fail to complete their growth.

Table 19. Number of sprouts each year in a clump of *Leleba multiplex*

Year investigated	1955	1956	1957
Number of undeveloped sprouts	5	4	15
Number of injured culms of sprouts	9	31	—
Number of fully developed new culms	12	10	35
Total number of sprouts or culms	26	45	50

Locality: Experimental Forest Station of Kyoto Univ.

B-2-2. Single culm forming species

Some species of sympodial type in tropical regions exhibit a single culm forming type. *Melocanna bambusoides* belongs to this type.

The groves of *Melocanna bambusoides* that are found in Assam, India show the culms standing like those of *Phyllostachys* species and are single culm forming (Photo. 16). This difference has already been described. Namely, buds on the basal part of a one-year-old culm in the soil, start growing in autumn and protrude their apices out of the soil during the rainy season through May into June. These new culms develop at about 1–2 meters away from the mother bamboo, have the appearance of being single culm forming such as the *Phyllostachys* species. Usually several new rhizomes develop from one mother bamboo, and these rhizome apices appear out of the soil to grow into a mature culm. This means that one mother bamboo produces one new bamboo, and the rate of a new bamboo production by mother bamboo is higher as compared with the *Phyllostachys* species. The number of the culms produced annually will be described in Section I, A–1, Part II.

B-3. Intermediate type

The *Sasa paniculata* and the *Pleioblastus pubescens* in Japan are the speceis that extend rhizomes and form clumps (Fig.1). This species extend thin rhizomes as far as several meters, protrudes up to 50–60 culms in clump form, again extends one rhizome several meters from the basal part of each culm and protrudes culms out of the ground. It repeats in the same way and thrives successively. Details on this propagation process will be presented later.

B-4. Studies on the question of Propagating process

It is an interesting subject to study on the reasons why clump forming species of sympodial type are widely distributed in the tropical regions.

The main points of interest are:

(1) Asexual propagating is advantageous against natural enemies and other unfavorable conditions. Further, in the tropical regions where bamboos are subject to those attacks inflicted by wild animals, a clump formation, above all bamboo species with thorny branches, has a protecting effect.

(2) Bamboos more or less prefer to be in the shade of trees. The trees which are standing among the clumps filling the spaces and offer favorable shade for the bamboos.

(3) In the regions where dry and rainy seasons are severe and long, the growth is much hindered in the dry season, generally in winter. Although temperature is high in winter, it is difficult for the rhizome of a bamboo to grow owing to dryness. It is only during the rainy season that new bamboos grow. Probably a short rhizome is suitable for monsoon weather.

(4) It is an interesting phenomenon that *Melocanna* species is found in such tropical regions as Assam, India, because the rhizome of this species thrives on long extending. In this regions, the rainfalls are generally well distributed and favour the growth of rhizomes. Therefore their rhizomes grow from autumn to winter and their apices develop into culms from spring to early summer.

(5) The *Phyllostachys* species in Japan sometimes form clumps at such times when the conditions of the soil become unfavorable. The tropical type forming clump will be a kind of regressive formation. The origin of bamboo may be considered to be in the monopodial type. This should be noted particularly, and studies on the chromosomes are being carried on, in cooperation with Prof. Dr. K. Yamashita and Assist, Y. Inamori.

References or note: 1) Dipped in culture solution, buds are being tested for their growth at the moment.

2) Transaction, Jap. Forest. Soc. No. 61 and 64, 1952 and 1955.

3) Mature bamboos refer to all bamboos, one year old or older now standing.

4) The silviculture and management of the bamboo. Dehli, India, 1940.

5) This is the situation in natural groves. If they are taken care of artificially, when fertilizers are applied for instance, many morenew culms can be produced.

C. Ingredients contained in young Sprouts and the matured Culms.

C-1. Nutritive value as food

The edible sprout of *ph. edulis* is nutritiously valuable. The fol-

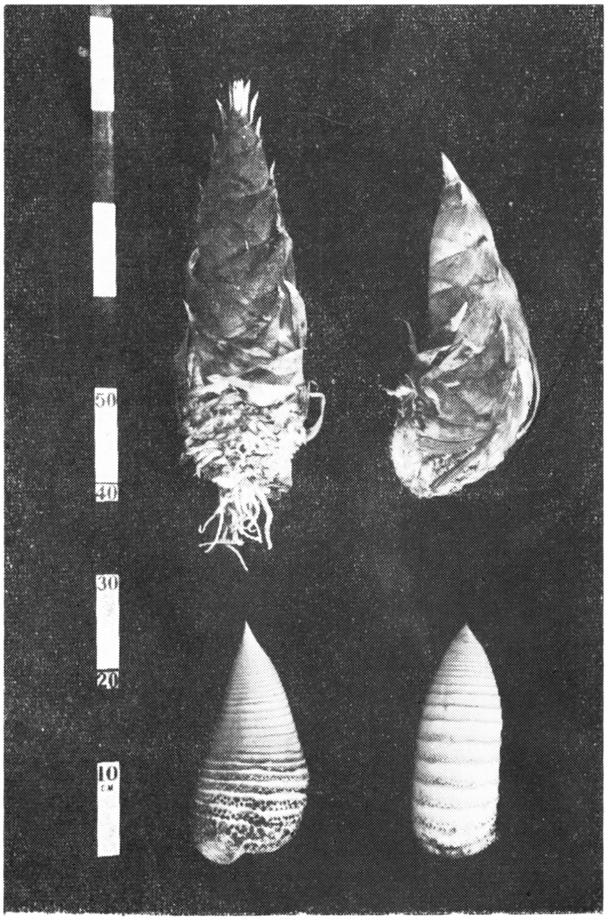


Photo. 24. Edible sprout of *ph. edulis*: (Left); poor quality. (Right); Good quality.

Table 20. Analytical results of bamboo sprouts (per 100g fresh matter)

(1) Sprout of *Phyllostachys edulis*

		Fresh matter	Canned food
Crude protein		2.5 g	1.9 g
Crude fat		0.2 g	0.1 g
Carbohydrates	sugar	2.9 g	2.9 g
	crude fiber	1.0 g	1.8 g
Water content		92.5%	92.8%
Calorie		23 cal.	20 cal.
Ash		0.7 g	0.4 g
Lime		1mg	1mg
Phosphorus		43mg	26mg
Iron		7mg	1mg
Vitamin	A	50 i.u.	50 i.u.
	B_1	0.10mg	0.05mg
	B_2	0.08mg	0.05mg
	C	10mg	0

by M. Kubo

(2) Sprout of *Phyllostachys edulis*

Portion		Water content (%)	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Carbohydrate (%)	Ash (%)
Edible sheath		87.34	2.61	0.35	1.15	6.88	1.67
Edible flesh	base	90.62	1.38	0.17	1.25	5.65	0.93
	middle	91.26	1.71	0.22	0.89	4.78	1.12
	top	89.70	2.72	0.28	0.42	5.50	1.39

Locality: Otokuni, Kyoto

lowing tables show the results of studies by Dr. S. Kagawa and Mr. Kubo.

The nutritive value of the bamboo sprout as shown in the above tables is roughly comparable to that of the onion. Tyrosine, a nitrogen containing constituent, is contained in the bamboo sprout in a large quantity (4 %). This is one of the factors responsible for the rapid growth of a sprout, which we are studying.

The contents of constituents vary according to the different parts of the bamboo sprout. In the parts of soft tissue, close by the apex, where less coarse fibers are contained, proteins are rich. The lower parts, especially the portion where the culm sheaths peeled off,contains less protein and more coarse fibers.

C-2. Inorganic substances contained in sprout and mature culm

Knowledge about the requirements of a bamboo for inorganic nutrients is indispensable for cultivating bamboos. The fluctuation of the content of inorganic nutrients in the different parts of the sprout or the shoot will be shown in Table 21.

Table 21. Analytical results of shoot or sprout

(A) **Each portion of** *Phyllostachys edulis* shoot

Length	Water content (%)				Total-N (%)				Total-P_2O_5 (%)				Total-K_2O (%)			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
332 cm	91.84	91.44	76.24	81.25	6.74	3.30	1.27	0.84	2.27	1.00	0.35	0.32	8.75	6.25	2.75	1.25

(B) **Each portion of** *Phyllostachys reticulata* shoot

Length	Water content (%)			Total-N (%)			Total-P_2O_5 (%)			Total-K_2O (%)		
	1	2	3	1	2	3	1	2	3	1	2	3
433 cm	90.10	89.00	78.30	5.29	1.74	0.71	2.09	0.59	0.25	7.10	3.35	0.65

Remarks; *Ph. edulis* 1 and 2, and *Ph. reticulata* 1 and 2 represent the portion of sprout covered with sheath.
Ph. edulis 3 and 4, and *Ph. reticulata* 3 represent the lower portion of new culm that finished growing and had no sheath.

(c) **Content of growth-hormones in bamboo sprouts** (*Ph. edulis*)

Length	Edible flesh		Sheath	
	Top	Middle	Not edible sheath (outside)	Edible soft sheath (inside)
28-32cm	3.0-6.0	3.0-5.0	1.2-14.0	0.6-0.9

Remark; The quantities of natural hormones were tested by stem-curvature test.

The above table shows the analytical results of a growing bamboo shoot which had completed its growth with its culm sheaths peeled off at the lower part, while the upper part was still in the progress of growth, being clasped with sheaths (Table 21).

In the Table 21, the content of N, P_2O_5 and K_2O are shown to be higher in the growing parts of the shoot and lower in the parts of the shoot where the growth is completed.

In a mature culm, every portion shows a decrease in the rate of consuming inorganic substances. For instance, the mean values on N, P_2O_5, K_2O and SiO_2, in some 2-3 year-old *Ph. reticulata*,[1)] are 0.3, 0.1, 0.4, and 0.1% respectively (Table 22. (1) (2)). The analytical results from *Leleba multiplex* (1-2 years old),[2)] a clump-forming type, are as shown in Table 22-(3), and they are not much different from the results of the *Ph. reticulata* except for some increase of K_2O content.

Table 22. Analytical results of the culm, leaves and rhizome of a bamboo

(1) *Phyllostachys reticulata* (1-2 years old) (% on air dry matter)

Portion of bamboo		Total-N (1)	Total-P_2O_5 (2)	Total-K_2O (3)	Total-SiO_2 (4)	Total-Ash (5)
Culm	Top	0.27-0.34	0.24-0.34	0.48-0.94	0.53-0.37	1.53-2.10
	Middle	0.20-0.24	0.14-0.23	0.48-1.00	0.43-0.23	1.24-1.80
	Basal	0.16-0.21	0.17-0.22	0.44-1.00	0.33-0.23	1.10-1.77
	Under ground	0.30-0.41	0.20-0.34	0.41-0.75	0.87-0.57	1.55-1.90
Leaves		1.96-2.04	0.23-0.24	0.39-0.64	7.80-9.23	13.95-14.60
Rhizome		0.51-0.62	0.16-0.18	0.70-1.40	—	4.00-5.70

(2) *Phyllostachys edulis* (1-2 years old) (% on air dry matter)

Culm	Top	0.18-0.26	0.11-0.24	0.25-0.58	0.37-0.33	0.83-1.20
	Middle	0.13-0.20	0.11-0.22	0.54-0.75	0.30-0.23	1.00-1.50
	Basal	0.13-0.23	0.15-0.27	0.83-1.34	0.23-0.20	1.50-2.80
	Under ground	0.14-0.32	0.14-0.36	1.00-1.29	0.37-0.87	1.72-2.80
Leaves		1.88-2.30	0.22-0.25	0.40-0.64	4.23-6.33	7.88-9.20
Rhizome		0.44-0.32	0.18-0.22	0.75-1.32	—	4.00-4.80

Locality: Kamigamo, Kyoto (Jan., Feb. 1959)

(3) *Leleba multiplex* (1-2 years old)…clump type.

(% on air dry matter)

		(1)	(2)	(3)	(4)	(5)
Portion of culm		Total-N	Total-P_2O_5	Total-K_2O	Total-SiO_2	Total-Ash
Culm	Middle	0.18-0.20	0.08-0.09	1.08-1.18	0.63-0.60	2.10-2.20
	Basal	0.20-0.20	0.09-0.10	1.04-1.04	0.50-0.60	1.80-2.10
	Under ground	0.26-0.36	0.12-0.14	1.38-1.40	1.30-1.00	3.80-3.30
Leaves		1.99-2.30	0.30-0.37	1.50-1.56	8.47-9.57	11.70-12.40
Branch		0.36-0.52	0.12-0.16	0.98-1.00	4.93-3.00	6.80-5.00
Root		0.51	0.15	0.90	5.97	8.7

Locality: Kamigamo. Kyoto (Aug. 1959)

(4) *Melocanna bambusoides* (1-3 years old)…Single culm type. (% on air dry matter)

		(1)	(2)	(3)	(4)
Culm	Middle	0.20-0.24	0.08-0.11	0.26-0.69	0.30-1.55
	Basal	0.17-0.23	0.08-0.12	0.35-1.14	0.40-1.13
Leaves		2.08-2.21	0.36-0.44	1.02-1.28	8.40-11.95
Rhizome		0.34-0.41	0.16-0.25	0.66-1.57	1.13-1.38

Locality: Assam, India (Mar, 1959)

D. Variation in Size among individual Culms

D-1. Bamboo species of monopodial type

Bamboos grown even in the same year and at the same site differ in sizes. The number and sizes of the culms that developed every year in the same bamboo grove are as shown in Tables 23 and 58.

For instance, even the good groves of the *Ph. reticulata* under good conditions produced culms of the sizes 4–13 cm in diameter at eye height. It is important for managing bamboo groves to know what is responsible for this difference. Although a number of causes may be given, one must be aware beforehand that these causes do not act independently but are mutually in connection with complexity.

Table 23. Yearly distribution by diameter of the number of newly grown culms in a grove of *Ph. reticulata* and *Ph. edulis*

(A) *Phyllostachys reticulata* grove (ordinary site) (per 0.1 ha)

Locality; Mukomachi, Otokuni, Kyoto

Diameter at eye height (cm) / Sprouted year	2	3	4	5	6	7	Total number	*Soku* (bundle)	Average diameter at eye height (cm)
1953			30	80	110	20	240	41	5.5
1954	10	50	60	100	10	10	240	26	4.3
1955	20	30	50	100	90	30	320	46	4.9
1956	20	60	120	70	40		310	32	4.2
1957	20	20	80	140		20	280	34	4.9

Remark; *Soku* is the marketing unit in Japan as shown in Table 36

(B) *Phyllostachys edulis* grove (good site) (per 0.1 ha) Locality; Nagaoka, Otokuni, Kyoto

Diameter at eye height (cm) / Sprouted year	8	9	10	11	12	13	14	15	16	Total number	Average diameter at eye height (cm)
1955	1	4	13	21	24	24	20	21	3	131	12.9
1956			4	3	14	10	7	7	1	46	12.8
1957			5	7	19	25	13	3	4	76	12.8

a. Relation between the size of culm and rhizome

Regarding the bamboo species thriving on the buds of rhizomes, the size of the rhizome is considered to be the factor affecting also the size of a culm. Therefore details must be examined first.

If rhizomes are the same age in the same species, large-size culms tend to develop from thick rhizomes while small-size ones from thin rhizomes. This trend is seen also among all species, that is, the rhizomes of the species with large-size culms are larger than those of the species producing smaller culms. But the relation of the size of a culm to that of a rhizome varies according to the conditions. In *Pleioblastus pubescens*, whose rhizomes lose vitality in several years, a clear relation can be observed. Namely, the rhizomes of a connected group belonging to a system were excavated in order to compare with two-year-old rhizomes and their one-year old culms. The result is as shown in Fig. 16. This figure clearly shows

Fig. 16. Relation between the diameters of rhizomes (2 years old) and the culms (1 year old) on *Pleioblastus pubescens* at Kamigamo, Kyoto in 1956.

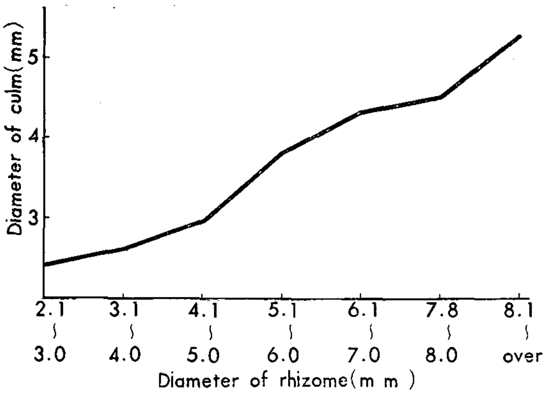


Table 24. Relation between the diameters of rhizomes and the culms of *Phyllostachys nigra*

Diameter of culm in grade (1) (cm)	Diameter of the rhizome (2)			(1)/(2)			Number of samples
	Maximum (cm)	Minimum (cm)	Average (cm)	Maximum	Minimum	Average	
0.8-1.0	1.5	0.8	1.1	1.10	0.50	0.85	10
1.1-1.3	1.5	0.9	1.2	1.30	0.75	1.01	19
1.4-1.6	1.6	1.0	1.2	1.59	0.82	1.21	24
1.7-1.9	1.7	1.0	1.3	1.85	1.10	1.43	31
2.0-2.2	1.6	1.0	1.4	1.97	1.20	1.53	21
2.3-2.5	1.6	1.2	1.4	2.10	1.31	1.72	21
2.6-2.8	1.8	1.1	1.4	2.50	1.72	1.96	11

Remark: Diameter of culm was measured at 30 cm above ground.

Locality; Mukomachi, Kyoto

the tendency that the thicker the rhizomes are, the larger the culms.

This phenomenon had also been comfirmed from the relation between the size of a one-year-old culm and the weight of a two-year-old rhizome of unite length.

Table 25. Relation between the diameters of rhizomes and culms of *Phyllostachys reticulata*

Site grade	Good grove			Poor grove		
	Maximum	Minimum	Average	Maximum	Minimum	Average
(A) Diameter of rhizome	3.2 cm	1.5 cm	2.3 cm	2.5 cm	0.8 cm	1.5 cm
(B) Diameter of mature culm grown from the rhizome	10.8 cm	3.2 cm	6.2 cm	5.7 cm	0.2 cm	1.7 cm
$\frac{(B)}{(A)}$	3.4	2.1	2.7	2.3	0.3	1.1

Locality; Mukomachi Kyoto (1955)

Table 24 shows the relation of the size of rhizomes, 1–3 years old, to that of culms of *Ph. nigra.*

The relation was also investigated on the *Ph. reticulata,* with larger size culms than the *Ph. nigra,* both in good and poor groves. The results are arranged in Table 25 and Fig. 17. They show that both culms

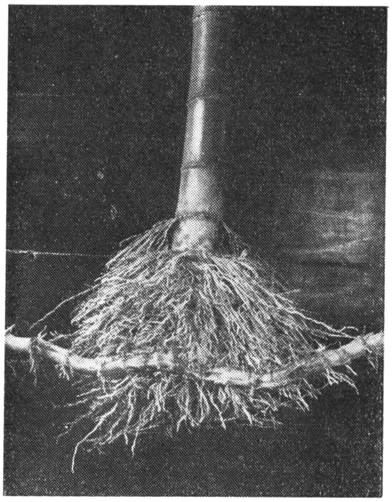


Photo. 25 (left)

A big culm of good qualilty (1 year old, diam. 7.5 cm at eye height) grown from a big and young rhizome (3 years old, diam. 2.5 cm) of *Phyllosachys reticulata*

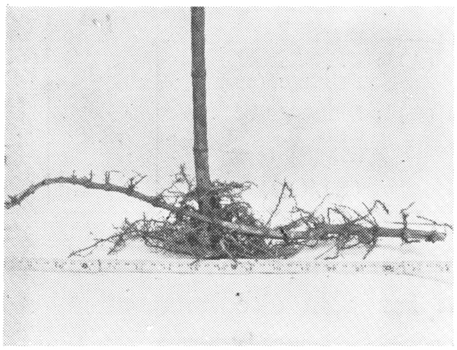


Photo. 26 (right)

A slender culm (1 year old, diam. 4.0 cm at eye height) grown from a slim and young rhizome (3 years old, diam. 1.5 cm) of *Phyllostachys reticulata* and rhizomes are larger in size in a fertile grove than in a poor one. The culm size generally is larger than the size of rhizome, and the ratio between both increases as the culm size becomes, 1, 2, 3 or 5 times larger.

It was found that the size of the culms developed on those same size rhizomes varies. The situation can be seen in Fig. 17. Various causes are responsible for it; for instance, when nutrients in the soil are scarce, newly grown culms become thinner.

A fertilizing test will show this more clearly. Even though the rhizomes produced small-size culm, they reproduced larger-size culms after fertilizer has been applied. Fertilizing test was done in March and April, 1956 at the experimental site of Kyoto University, and those rhizomes were dug out in November of the same year. The detail will be presented in the section dealing with fertilization.

The part of above results are tabulated and illustrated as shown in Table 26 and Fig. 18.

Table 26. Effect of fertilizing on the diameter of culms and rhizomes in the *Phyllostachys reticulata* grove

Item	Before fertilizing			1st year after fertilizing		
	Minimum (cm)	Average (cm)	Maximum (cm)	Minimum (cm)	Average (cm)	Maximum (cm)
(A) : Diameter of rhizome	1.1	1.4	1.9	1.1	1.4	1.9
(B) : Diameter of newly grown culm	0.4	1.5	2.8	1.0	2.0	3.1
(B)/(A)	0.4	1.1	1.5	0.9	1.4	1.6
Number of new culms grown in a year	80-83			152		

Locality: Expelimental Forest Station of Kyoto Univ., Kitaku, Kyoto

Table 27. Affection of clear cutting on the size of culms of *Phyllostachys reticulata* grove

investigated area: 0.1 ha.

Item	Culms grown before clear cutting			Culms grown in a year after clear cutting		
	Minimum (cm)	Average (cm)	Maximum (cm)	Minimum (cm)	Average (cm)	Maximum (cm)
(A) : Diameter of rhizome (cm)	1.5	2.4	3.0	1.3	2.2	3.2
(B) : Diameter of culm (at eye height) (cm)	2.9	6.4	9.3	0.8	1.6	3.1
(B)/(A)	1.9	2.7	3.1	0.6	0.7	1.0

Locality: Mukomachi, Kyoto (1954)

An example of the procedure for reducing the size of new culms when it has been discovered, after clear cutting, that there is a decrease of nutritional supply.

Fig. 17. Relation between the diameter of rhizomes and the culms on different site in the groves of the *Phyllostachys reticulata*
Locality: Kyoto 1955-1957

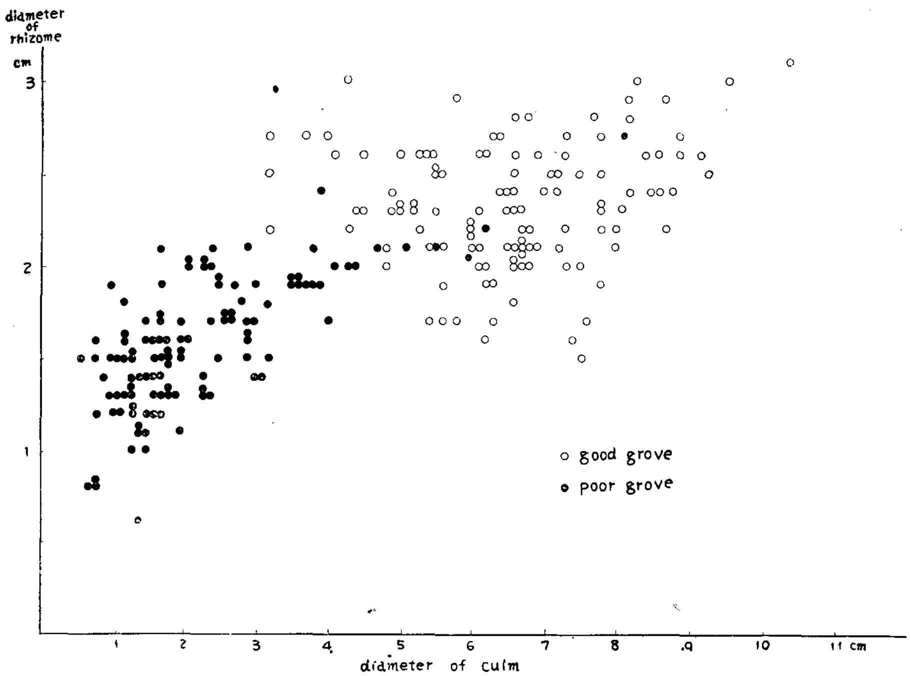
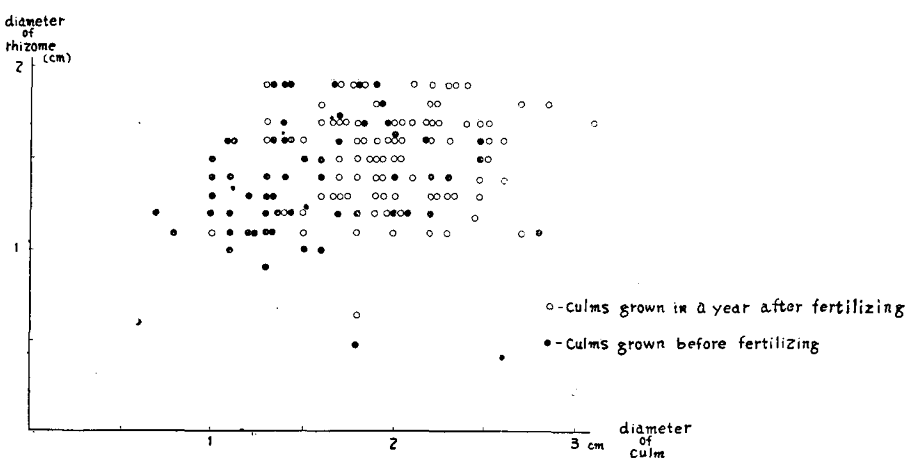
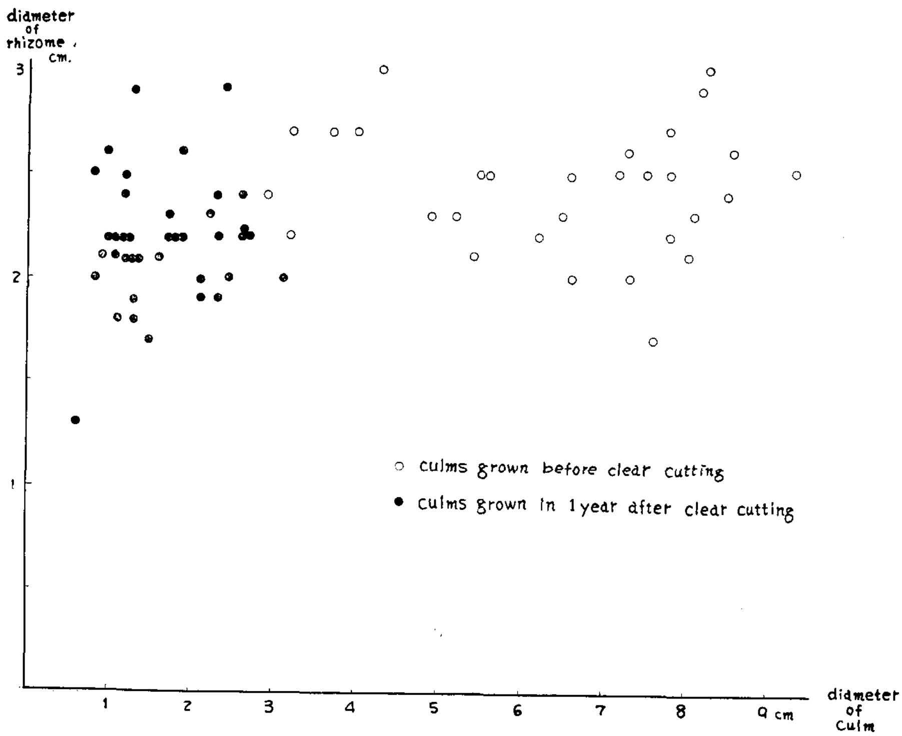


Fig. 18. Relation between the diameter of rhizomes and the culms effected by fertilizing in the *Phyllostachys reticulata* grove
Locality: Kamigamo, Kyoto 1956-1957



When all culms are cut, the nutritional supply is markedly decreased. Therefore the new culms that develop thereafter become slender though they are from the large-size rhizomes. The Table 27 and Fig. 19 will show the change.

Fig. 19. Relation between the diameter of rhizomes and culms affected by clear cutting in the *Phyllostachys reticulata* grove
Locality: Mukomachi, Kyoto 1955-1956



b. Relation between the size of culms and the age of rhizomes

This relation can be easily shown by the investigation on the *Pleioblastus* species with small size culms and short lived rhizomes. The sprouts with rhizomes of *Pl. pubescens* were transplanted in March, 1952 and everything including rhizomes was dug out in April 1955, and the number and the size of developed culms were recorded each year. The result is shown in Table 28. For instance, on the number and size of new culms developed in one year from rhizomes (per 1 m), five culms grew up from the two-year-old ones and these were also the largest in size, but only one small culm was newly grown from each four-year-old ones. This phenomenon reveals that two-year-old rhizomes are most vigorous, and that four-year-old ones are too old, having lost their vitality in the case of the *Pl. pubescens*. After the

Table 28. Number and diameter of new culms grown from 2–4 year old rhizomes belong to a rhizome system of *Pleioblastus pubescens*

Age of rhizome	Rhizomes		New culms grown from their rhizomes in 1955	
	Diameter (mm)	Length (cm)	Number	Diamete (mm)
2 years old, grown in 1954	4.0	412	21	4.6
3 years old, grown in 1953	4.1	339	5	3.8
4 years old, grown in 1952	4.1	127	1	3.1

Locality: Kamigamo, Kyoto (1955)

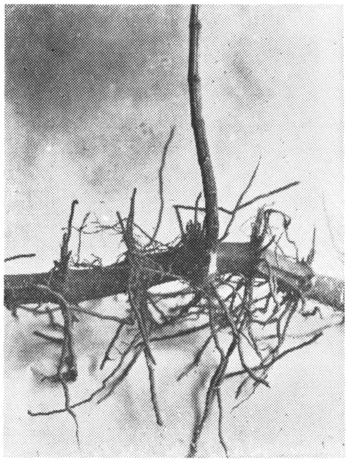


Photo. 27

A slim culm (1 year old, diam. at the base 1 cm) grown from 8–9 year old rhizome, diam. 2.7 cm.

Table 29. Relation between the age of rhizome and the number, diameter of their newly grown culms. (*Phyllostachys reticulata* grove)

Site (soil condition)	Rhizome		New culms developed from each year rhizome			
			Diameter			Number
	Age (years)	Average diameter (cm)	Maximum (cm)	Minimum (cm)	Average (cm)	
Good	2	2.1	6.0	5.6	5.8	2
	3-6	2.3	9.3	3.2	6.4	52
	7-8	2.5	6.7	4.5	5.8	8
	9-11					0
Poor	2					0
	3-6	1.9	3.2	1.7	2.5	5
	7-8	1.8	4.0	2.4	3.0	5
	9-11	1.7	2.8	1.7	2.3	3

Locality: Mukomachi, Kyoto (1954~55)

loss of vitaltiy in rhizome, new culms are developed also from the buds at the basal parts of mother bamboo and they show a clump-like propagation.

The above phenomena of the *Phyllostachys* species with larger-size culms and longer lived rhizomes are explained below. In order to investigate on the size of culms and the age of rhizomes of *Ph. reticulata*, the connected rhizome systems were dug up. The results are shown in Tables 15, 29 and 30.

The Tables 15, and 29, show that 2 ~ 6 year old rhizomes produce generally great number of culms and larger-size culms. But this phenomenon in the poor grove is not so clear as in the good grove.

Table 30 shows that small size culms, above all smaller than 1 cm in diameter at eye height, are generally produced from the old rhizomes of over 8 years. In this case, the culm size is smaller than the size of rhizome.

Table 30. Relation between the diameter of the culms and the rhizomes of over 8 years old in the old groves of the *phyllostachys reticulata*

(1)	(2)	(3)			(4)	(5)
Site (Soil condition)	Diam. of 1 year old culms (at 10cm height above the ground) (cm)	Number of their rhizomes			Diam. of the rhizomes of over 8 years old (Average) (cm)	(2) / (4)
		Over 8 years old	Below 7 years old	Total		
Good	0. 1-0. 4	18	0	18	2. 3	0. 1
	0. 5-1. 0	27	0	27	2. 4	0. 3
	1. 1-1. 4	4	0	4	2. 5	0. 6
Poor	below 0. 1	6	0	6	1. 9	?
	0. 1-0. 4	9	0	9	2. 0	0. 2
	0. 5-1. 0	7	0	7	2. 1	0. 3

Locality: Kyoto (1953~55)

Table 31. Content of total nitrogen in various age of rhizomes before and after sprouting period of *Phyllostachys reticulata* and *Ph. edulis.* (% on dry matter)

Species	*Phyllostachys reticulata*				*Phyllostachys edulis*		
Date / Age of rhizome	Before sprout appearance, Feb. 26 (%)	Just before sprout appearance, May 16 (%)	Period of most active sprouting, June 18 (%)	After finished sprouting, July 22 (%)	Before sprout appearance, Apr. 1 (%)	Period of most active sprouting, Apr. 25 (%)	After finished sprouting, May 16 (%)
1 year old	0. 61	0. 88	1. 08	0. 53	0. 73	0. 98	0. 49
2 years old	0. 60	0. 74	0. 81	0. 52	0. 64	0. 67	0. 58
3 years old	0. 59	0. 62	0. 66	0. 50	0. 65	0. 76	0. 60
4 years old	0. 59	0. 62	0. 57	0. 41	0. 49	0. 55	0. 54
5 years old		0. 57	0. 55	0. 42	0. 46	0. 64	0. 43
6 years old		0. 47	0. 48	0. 46	0. 53	0. 58	0. 41

Locality: Fushimi, Kyoto (1957)

According to the age of rhizome, its contained nutrition is as shown in Tables 31, 32–A, B. It is found that soluble nitrogen and phytin are especially contained more in 2—5 year old rhizome than in the older ones.

Table 32. Seasonal variation of nutrient content in rhizome of *Phyllostachys edulis*

Locality: Fushimi, Kyoto (1954)

A. Before sprouts-appearance of sprouts (Feb. 4)

Age of rhizome		1 year old (%)	2-5 years old (%)	6-10 years old (%)
Nitrogen Compound	Total N	0.99	0.96-0.90	0.72-0.47
	Soluble N	0.48	0.59-0.53	0.41-0.24
	N in protein	0.51	0.41-0.31	0.31-0.20
	Protein	3.18	2.56-1.93	1.93-1.25
Carbohydrate	Invert sugar	3.05	2.71-2.03	2.27-1.55
Phosphorous Compouud	Total P_2O_5	0.445	0.524-0.471	0.452-0.356
	Phosphotide P	0.029	0.027-0.019	0.019-0.016
	Neuclein P	0.074	0.041-0.033	0.030-0.024
	Phytin and inorganic P	0.342	0.471-0.403	0.403-0.314
Ash		2.4	2.7-2.5	3.4-2.7
Water content			66.9-56.8	56.2-44.6

B. After termination of sprouts-appearance (July. 7)

Age of rhizome		1 year old (%)	2-5 years old (%)	6-10 years old (%)
Nitrogen compound	Total N	1.10	0.60-0.49	0.43-0.35
	Soluble N	0.48	0.28-0.25	0.20-0.13
	N in protein	0.62	0.32-0.24	0.25-0.20
	Protein	3.87	2.00-1.50	1.56-1.25
Carbohydrate	Invert sugar	1.12	2.46-1.01	1.14-1.07
Phosphorous compound	Total P_2O_5	0.327	0.466-0.394	0.383-0.283
	Phosphotide P	0.023	0.020-0.016	0.017-0.015
	Neuclein P	0.124	0.032-0.024	0.021-0.016
	Phytin and inorganic P	0.180	0.418-0.347	0.347-0.249

c. Number of bamboos that grew on a rhizome of a fixed length

In the case of culms that are developed from rhizome of a fixed length and of the same size and age, the size of newly developed culms, when they are numerous, usually become smaller.

Yet, this variety also depends upon the distance from the mother bamboo, and the soil condition, etc.

d. Distance from mother bamboo

The nutrients produced by the assimilation of mother bamboos tend to move in the growing direction of the rhizome. This was confirmed in the experiments by the use of radio isotope P^{32},[2] and by the other method[3] in the *Phyllostachys* grove. The buds nearest the mother bamboo were observed to develop into culms of larger size than buds located at a distant from it.

Those facts are also confirmed by the investigation on the culms that grew on a rhizome of *Pl. pubescens*.

e. Difference of a rhizome system

A close relationship between the mother bamboo and the newly grown bamboo was found in our investigation of the rhizome system. In old bamboo groves having been left under natural environments without tending for long years, for instance, the large-size bamboos generally synthesize a great amount of nutrients by vigorous assimilation of many green leaves and produce large-size rhizomes and culms alternately. On the contrary, a poor bamboo only repeats a poor cycle.

In practice, when all rhizomes in a system with large-size culms were being excavated in succession in the natural bamboo groves, it was found that the connected rhizomes were practically all large-size and many of their culms were large. Then, the small-size culms in the same bamboo grove were dug up together with the rhizomes connected to them. The rhizomes of this connected system were generally small in size and bearing many culms of small size. These results are shown in Table 33 and Fig. 20.

From the above results, concluding that each system of a connected rhizome under natural conditions produces itself culms of different sizes,

Table 33. Relation between the diameter of the rhizomes and that of culms grown from them belong to a rhizome system in the same grove

Species (grove)		Rhizomes				Culms			
		Diameter			Total length (m)	Diameter (at base)			Number
		Maximum (cm)	Minimum (cm)	Average (cm)		Maximum (cm)	Minimum (cm)	Average (cm)	
Phyllostachys reticulata grove	A	2.1	1.5	1.9	41.50	4.9	3.2	3.9	10
	B	1.6	1.3	1.4	15.15	3.2	1.8	2.3	6
Phyllostachys edulis grove	A	3.0	2.0	2.4	80.27	17.4	8.2	13.5	16
	B	2.6	1.9	2.2	36.63	9.0	3.3	6.1	11

Locality : Nagaoka, Kyoto (1958)

Remark ; A shows rhizome system with large-size culm.
B shows rhizome system with small-size culm.

Fig. 20-a. A rhizome system with small-size culms excavated from an old grove of the *Phyllostachys edulis*

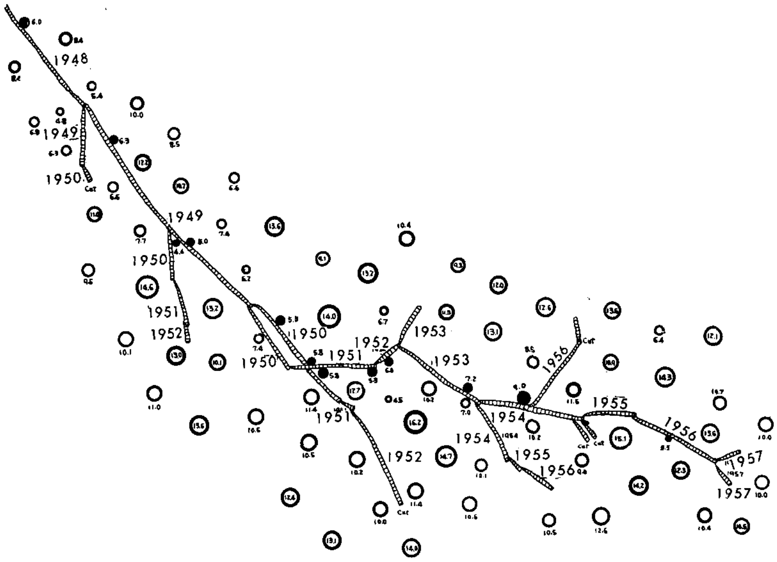
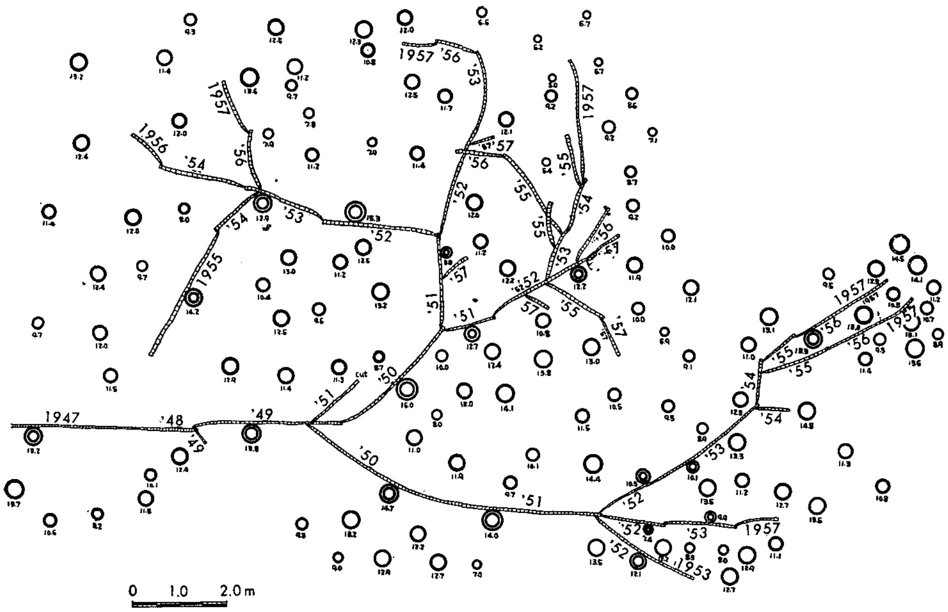


Fig. 20-b. A rhizome system with large-size culms excavated from *the same grove as shown in Fig. 20-a*



●, ◎, 6.3 ; **Culms developed from the rhizome excavated and its diameter at eye height (in cm)**

○ ; **location of culms developed from other rhizome system**

' 49 ; **Rhizome and its developed year**

Investigated in Mukomachi Kyoto. 1957

arises a concept that strains may differ individually or hereditarily.

But, of course, even a connected system of rhizomes with small-size culms could be improved to grow into larger new rhizomes, and then produce larger-size culms in return, by being fertilized. Therefore, the differences in the sizes of culms of different systems are not hereditary, and so the cultivation of bamboos of improved quality can be expected by a better treatment.

f. Time of sprout development

Among the same species, the sprouts that develop earlier, generally tend to develop into larger culms, while the late ones, into small culms. This has already been referred to A-1 and A-2.[3]

g. On-year and off-year (good sprouting year and poor sprouting year)

Years bearing more sprouts and those bearing fewer usually occur alternately every year. while in a good sprouting year new culms are large-size, in a year when sprouts are less in number, the size of new culms does not become large as shown in Table 34.[4] This, however, does not appear to be of a permanent hereditary nature, as it was confirmed by an experiment

Table 34. Number of new culms developed in off or on year of the bamboo grove

(1) *Phyllostachys reticulata* grove (per 0.1 ha)

Site	On or off year	Year	New culms				Mature culm before harvesting		Locality
			Number	Diameter at eye height			Number	Average diameter at eye height (cm)	
				Maxi mum (cm)	Mini-mum (cm)	Ave-rage (cm)			
Good	off year	1954	70	8.0	4.3	6.4	530	9.2	Nagaoka, Kyoto
	on year	1955	110	10.2	5.0	7.4	510	8.8	〃
Poor	off year	1956	290	5.0	2.0	3.3	1260	3.6	〃
	on year	1957	390	5.0	2.0	3.5	1440	3.8	〃

(2) *Phyllostachys edulis* grove (Per 0.1 ha)

Site	On or off year	Year	New culms				Mature culms before harvesting		Locality
			Number	Diameter at eye height			Number	Average diameter at eye height (cm)	
				Maxi-mum (cm)	Mini-mum (cm)	Average (cm)			
Good	off year	1956	46	15.9	10.7	12.9	655	13.9	Nagaoka, Otokuni, Kyoto-pref.
	on year	1957	76	15.8	9.6	12.8	634	13.2	
Poor	off year	1954	37	10.8	2.2	7.2	619	8.7	Fushimi, Kyoto city
	on year	1955	94	12.9	5.7	9.8	617	9.5	

showing that it can be controlled by fertilizing and other means.

h. Views

Factors affecting the sizes of those culms that develop in the same bamboo grove have been described in the preceding page. This may reveal that, it is not an easy task to eliminate the difference in culm size. However, it is possible to reduce the range of the differences among individual culms. Moreover, with rhizomes of the same size it can be expected that they will develop larger–size culms or produce large–size rhizomes which in turn will grow larger–size culms. Thus, it is important to improve the management of bamboo groves in the relation between mature bamboos and rhizomes by applying a better cycle.

D-2. Bamboo species of sympodial type

Melocanna species also produce culms of various sizes. What has been described above may also be applied to this case. Although these species are different in the apices of rhizomes that protrude out of ground to become culms, the culms become markedly larger than rhizomes under normal conditions and once above the ground their nature resembles *Phyllostachys* in the relation between the size of rhizome and culm. For instance, the investiga tion on a grove of *Melocanna bambusoides* carried out by the author and his assistant, shows that the diameters of rhizomes were 2.5–3.5–4.1 cm while the diameters of culms at eye height were 5.5–6.2–6.7 cm.

In bamboo species that form clumps, the buds on the basal part (underground) of one-year-old culms usually protrude out of the soil and they become new culms. Therefore, the size of new culms is more affected by the quality of mother-mature culms than by rhizomes. Thus, in bamboo groves under natural condition when a clump has large-size culms, they develop many large-size culms every year and a clump with a small-size culms develop many small-size culms. This difference in size of those culms among the clumps of the same species is neither hereditable nor permanent, and can be artificially improved. For instance, in a fertilizing test with *Leleba multiplex*, conducted by the author and S. Ueda, the culms that developed by fertilizer application were not only longer than those developed before being fertilized, but also increased greatly in number (Table 56).

D-3. Relation between the qualities of sprout and mature culm

According to our investigation, a sprout has the same qualities as its mature culm. That is to say, the whole number of the nodes of a mature culm is found on a sprout (Photo. 4) and a bamboo sprout of good quality develops into a mature culm of good quality. For this reason, the researches on sprouts and buds are also of great importance. The study on the relation between the mature bamboo and the sprout or the bud, is now being carried out in view of determining this relation.

NOTE : 1) Ecology of *Sasa* and its applcation. Series: Illustration of Forestry, NO., 49, Dec., 1956.
2) Transaction. KANSAI Branch, Jap. Forest. Soc. No. 6, Nov., 1960.
3) ibid.

E. Size and Quality of Culm

Correlations are found among the factors of culms such as diameter, length and weight. The data presented here on *Ph. reticulata*, *Ph. edulis* and *Ph. nigra* were obtained in the vicinity of Kyoto. However, the culms of the same species with the same diameter may sometimes disagree in culm length,[1] internodal length, weight of culm or weight of branch and leaf. This individual variation is caused by soil conditions, density of groves and other conditions. What should be considered here is that, since the growth of a culm is quite dependent upon the assimilation of mature bamboos or the nutrients reserved in rhizomes, the quality of the culm may be affected to a considerable extent by the nature of the mature bamboo as well as by the natural environmental factors.

E-1. Culm length

The culms become longer as the diameter at eye height increases. Yet their relation curve is not linear. The culms of larger size in diameter have smaller rates of increase in length, as shown by the curves in Fig. 21. The largest culm length of those bamboos produced in Japan is 20 m (12.1 cm in diameter at eye height) for *Ph. reticulata*, 21 m (19.0 cm in diameter at eye height) for *Ph. edulis* and 6 m (3.0 cm in diameter at base) for *Ph. nigra*. Even in the case of culms of the same diameter, the individual culm length in the groves of superior quality generally exceeds the culm length in the groves of poor quality. When the fluctuation of culm lengths, each under the same diameter grade, is expressed in terms of deviation coefficient, the range of deviation of the culm length is smaller in the culms of larger diameter grade, since culms with larger diameters

Table 35. Relation between the diameters at eye height and whole length of culms

(1)

	Culm length \ Diameter at eye height (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Phyllostachys reticulata	Maximum (m)	3.50	6.80	8.25	10.88	12.30	13.50	15.56	17.70	17.71	19.13	19.11	19.74					
	Minimum (m)	1.94	3.60	4.85	5.78	7.35	7.63	9.80	11.88	13.35	15.40	15.89	18.59					
	Average (m)	2.93	5.44	6.69	8.26	9.79	10.93	12.76	13.99	15.75	17.27	17.89	18.99					
	Standard deviation (m)	0.45	0.92	0.92	0.96	1.30	1.38	1.24	1.46	1.17	0.84	0.93	0.53					
	Coeffifient of variation (%)	1.53	16.9	13.8	11.6	13.3	12.6	9.7	10.4	7.4	4.9	5.2	2.8					
	Number of samples	13	18	23	31	21	38	35	24	23	20	10	3					
Phyllostachys edulis	Maximum (m)			6.42	9.90	9.48	11.58	11.52	15.55	14.15	15.75	17.90	17.73	18.11	20.05	19.71	21.15	21.63
	Minimum (m)			5.40	5.90	7.08	7.00	8.31	9.54	10.50	11.49	11.72	13.92	15.60	16.53	16.05	17.25	21.00
	Average (m)			5.96	7.16	8.35	9.16	10.21	11.36	12.07	13.34	14.00	15.24	17.74	17.75	17.79	19.26	21.32
	Standard deviation (m)			0.40	0.94	0.83	0.89	0.92	1.17	0.82	1.07	1.57	0.98	0.85	0.97	1.71	1.03	0.45
	Coefficient of variation (%)			6.7	13.1	9.9	9.7	9.0	10.3	6.8	8.0	11.2	6.4	4.8	5.5	9.6	5.3	2.1
	Number of samples			4	15	22	33	37	35	34	30	14	18	12	13	10	10	2

Table 35. Relation between the diameters at eye height and whole length of culms

(2) **Retouched value expressed below**

ph. reticulata $H=2.938\ D^{0.7550}$ H=culm length (m)

ph. edulis $H=2.250\ D^{0.7753}$ D=diameter, at eye height (cm) in *Ph. reticulata* and *edulis*, at 30 cm above the ground in *Ph. nigra*.

ph. nigra $H=2.585\ D^{0.7664}$

Species \ Diameter at eye height (cm)	1	2	3	4	5	6	7	8
Ph. reticulata (m)	2.94	4.96	6.73	8.37	9.90	11.36	12.77	14.13
Ph. edulis (m)			5.27	6.59	7.84	9.03	10.17	11.28

Species \ Diameter at eye height (cm)	9	10	11	12	13	14	15	16	17
Ph. reticulata (m)	15.43	16.71	17.96	19.18					
Ph. edulis (m)	12.36	13.41	14.44	15.45	16.44	17.41	18.36	19.31	20.24

(3) **Culm length / Diameter at eye height**

Species \ Diameter at eye height (cm)	1	2	3	4	5	6	7	8
Ph. reticulata (m)	294	248	224	209	198	189	182	177
ph. edulis (m)			176	165	157	151	145	141

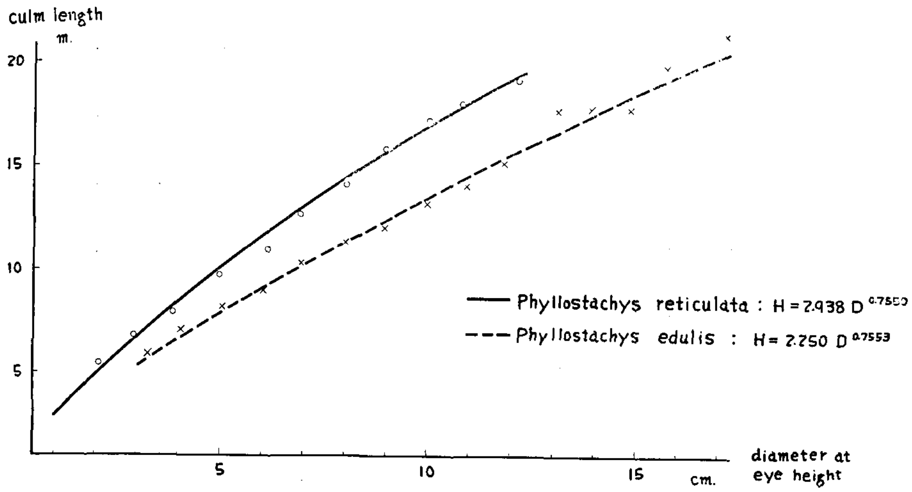
Species \ Diameter at eye height (cm)	9	10	11	12	13	14	15	16	17
ph. reticulata (m)	171	167	163	160					
ph. edulis (m)	137	134	131	129	126	124	122	121	119

at eye height become comparatively smaller. As compared with *Ph. reticulata* and *Ph. edulis* of culm length in the same diameter grade, the former is longer (Table 35. (1) (2), Fig. 21).

It has been a custom to multiply the girth at eye height by 60 to obtain the culm length. This custom is applicable to the culms over 6 cm in diameter in the case of *Ph. reticulata,* but it is 70–80 times for the smaller culms. In the case of *Ph. edulis,* the proportion is about 40 for culms over 10 cm in diameter, but it is not constant. In this case, the relation between culm length and diameter at eye height is as shown in Table 35 (3).

This table serves only as a mark, but presumption of the length from the diameter may be used as a mean to judge the quality of the culms or the soil condition where the culms are produced. The reason is, that among the culms of a certain diameter grade, longer ones can be regarded as better.

Fig. 21. Relation between the diameter at eye height and the length of a culm



E-2. Weight of culm

The weight of a culm is expressed by the term fresh weight in this report, because air dry weight varies according to the cutting season and the number of days after cutting. Fresh weight of culms commonly becomes heavier as its diameter increases, and the curve is a parabola as shown in Fig. 22. The maximum weight of one culm was 77 kg (17.3 cm in diameter at eye height) for *Ph. edulis,* 44 kg (12.1 cm) for *Ph. reticulata* and 13 kg (2.8 cm in diameter at the lower portion of a culm) for *Ph. nigra* in Kyoto region.

Even in a grade of the same diameter, the fresh weight of a culm from bamboo groves of superior quality tends to be heavier than that of a culm from groves of poor quality. As compared with *Ph. reticulata* and *Ph. edulis* of a culm of the same size in diameter, the former is heavier and the difference increases as the diameter becomes greater (Table 36). This is ascribed to the fact that *Ph. edulis* has a larger grade of tapering.

Fresh weight of the culms of each girth at eye height per *soku** is as shown in Table 36-(3). It seems that fresh weight per *soku* varies according to the size of a culm. It may be set roughly to 35 kg for *Ph. reticlulata* and 32 kg for *Ph. edulis.*

Table 36. Relation between diameter at eye height and fresh weight of a culm

(1)

	Diameter at eye height (cm.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
phyllostachys reticulata	Maximum (kg)	0. 27	1. 67	2. 33	3. 80	7. 00	9. 57	12. 60	19. 95	23. 80	30. 00	34. 44	44. 11					
	Minimum (kg)	0. 05	0. 25	0. 25	1. 35	3. 40	4. 15	7. 30	8. 43	15. 05	21. 20	26. 40	35. 86					
	Average (kg)	0. 16	0. 71	1. 36	2. 55	4. 77	6. 54	9. 75	13. 69	18. 56	25. 24	29. 90	40. 24					
	Standard deviation	0. 06	0. 32	0. 46	0. 56	1. 00	1. 35	1. 57	2. 41	2. 75	2. 17	1. 84	3. 39					
	Coefficient of variation (%)	37. 5	45. 1	33. 8	22. 0	20. 1	20. 6	16. 1	17. 6	14. 8	8. 6	6. 2	8. 4					
	Number of samples	13	18	23	31	21	38	35	24	23	20	10	3					
phyllostachys edulis	Maximum (kg)			1. 57	3. 69	5. 95	8. 30	11. 60	16. 50	22. 00	28. 80	29. 18	36. 36	45. 53	48. 45	56. 76	64. 68	77. 43
	Minimum (kg)			1. 34	1. 38	3. 50	4. 84	5. 80	8. 30	12. 35	14. 10	20. 05	26. 76	35. 75	38. 23	50. 55	53. 80	71. 13
	Average (kg)			1. 47	2. 52	4. 49	6. 22	8. 59	11. 85	15. 76	20. 47	25. 01	30. 70	41. 22	44. 75	53. 44	60. 85	74. 28
	Standard deviation			0. 09	0. 60	0. 63	0. 93	1. 26	2. 18	2. 07	3. 79	2. 71	2. 69	2. 86	3. 10	1. 53	3. 24	0. 45
	Coefficient of variation (%)			6. 1	23. 8	14. 0	14. 0	14. 7	18. 4	13. 1	18. 5	10. 8	8. 8	6. 9	6. 9	2. 9	5. 3	0. 6
	Number of samples			4	15	22	33	37	35	34	30	14	18	12	13	10	10	2

Table 36. Relation between diameter at eye height and fresh weight of a culm

(2) **Retouched value by below expressions**

phyllostachys reticulata	$W = 0.0750\ D^{2.5192}$	W = fresh weight of a culm (kg)
phyllostachys edulis	$W = 0.0906\ D^{2.3638}$	D = diameter (cm) at eye height of *Ph. reticulata.* and *edulis*, at 30cm above the ground of *Ph. nigra*
phyllostachys nigra	$W = 1.3895\ D^{2.0168}$	

Species \ Diameter at eye height (cm)	1	2	3	4	5	6	7	8
ph. reticulata (kg)	0.08	0.43	1.19	2.46	4.32	6.84	10.09	14.12
ph. edulis (kg)			1.22	2.40	4.07	6.26	9.01	12.35

Species \ Diameter at eye height (cm)	9	10	11	12	13	14	15	16	17
ph. reticulata (kg)	19.00	24.78	31.50	39.22					
ph. edulis (kg)	16.32	20.93	26.22	32.21	38.91	46.36	54.58	63.57	73.36

(3) **Number and fresh weight per** *soku*

Diameter at eye height (cm)	3	4	5	6	7	8	9	10	11	12	13	14	15
Number per *soku*	24	12	7	5	4	3	2	1.5	1.2	1.0	0.75	0.5	0.25
ph. reticulata (kg)	28.6	29.5	30.2	34.2	40.4	42.4	38.0	37.2	37.8	39.2			
ph. edulis (kg)	29.3	28.8	28.5	31.3	36.0	37.1	32.6	31.4	31.5	32.2	29.2	23.2	13.6

As to **air dry weight**, it is not easy to determine how many months after cutting, the culms get air dried. But air dry weight may roughly be regarded as 70% of fresh weight.

With regard to the culms of the sympodial type species, the results of the author's investigation in India is shown in Tables 37 and 38.

The fresh weight of a culm of *Dendrocalamus strictus*, *Bambusa arundinaceae* or *Melocanna* species tends to be somewhat greater than *Phyllostachys* species of the same size culm in diameter. Since the culm walls of the former 3 species are thick, their fresh weight of the same diameter seems to be heavier than that of the *phyllostachys* species in Japan.

* The "*Soku*" is the traditional unit of measure employed in handling and marketing bamboo culms. The number of culms per "*Soku*" relates to the diameter at eye height. See details in Table 36-(3). The "*Soku*" is a convenient unit for expressing the volume of bamboo standing in a grove as the number of "*Soku*" in a grove can be readily determined by measuring the diameter of the culm. Also this unit of measure is commonly used in expressing the yield of culms from experimental plots. Less commonly, experimental data is presented in terms of metric tons, but even when yields are expressed in this manner the weight is often estimated from the number of "*Soku*".

Fig. 22. Relation between the diameter at eye height and the fresh weight of a culm

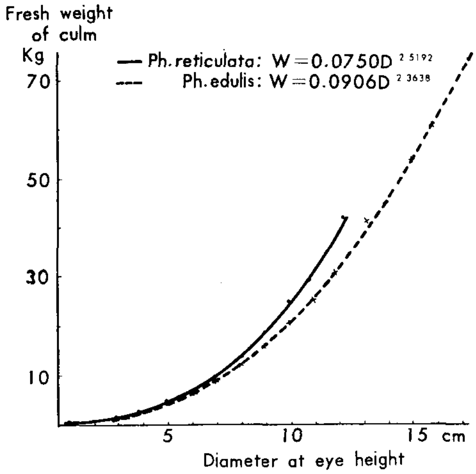


Table 37. Investigation on the culms of some species in the natural grove of India

Investigated at Feb. to Mar., 1959

Species		Diameter at eye height (cm)	Culm length (m)	Fresh weight (kg)	Clear length (m)	Locality
Dendroclamus strictus	large size	6	12.5	12.1	Branches are developed down to the first node above ground.	Balaghat (Madhya-pradesh)
	average	4	9.3	6.9		
Bambusa arundiaacea	large size	11.9	18.35	81.0	〃	Madras (Hasanur)
	average	5.3	8.48	20.1		
	average	7.3	18.22	31.2		Kerala (Nillambur)
Melocanna bambusoides	large size	7.1	19.4	14.9	7.4	Assam (Cachar)
	average	5.5	17.4	9.0	10.6	

Table 38. Weight of culms of *Dendrocalamus strictus*. (Angul Division, Orissa in India).

Locality, No.	Length class.	Green, freshly cut.			Air dry				Remarks
		Number of culms weighed	Average weight of a culm	Number of culms per ton.	Number of culms weighed	Average weight of a culm	Number of culms per ton.	Number of days taken to dry to a constant weight.	
			lbs.			lbs.			
1	18′-24′	830	10. 7±0. 24		830	6. 5±0. 15		117	*Weighing was carried on for 150 days, no constant weight was arrived at.
2	〃	190	8. 9±0. 43		190	4. 9±0. 29		*	
3	〃	500	10. 5±0. 27		500	5. 6±0. 16		109	
Average for the localities			10. 4±0. 17	215		6. 0±0. 11	373		
1	24′-30′	490	16. 3±0. 31		490	9. 6±0. 18		117	
2	〃	490	13. 9±0. 33		490	8. 2±0. 21		*	
3	〃	500	13. 3±0. 28		500	7. 2±0. 13		109	
Average for the localities			14. 5±0. 18	154		8. 3±0. 11	270		
1	30′-36′	180	23. 6±0. 52		180	14. 2±0. 30		117	
2	〃	820	23. 3±0. 47		820	13. 1±0. 25		*	
3	〃	500	21. 4±0. 44		500	12. 3±0. 29		109	
Average for the localities			22. 7±0. 30	99		13. 3±0. 17	169		
Average for all classes and localities			15. 9±0. 15	141		9. 2±0. 08	244		

by F. C. Osmantson, 1939.

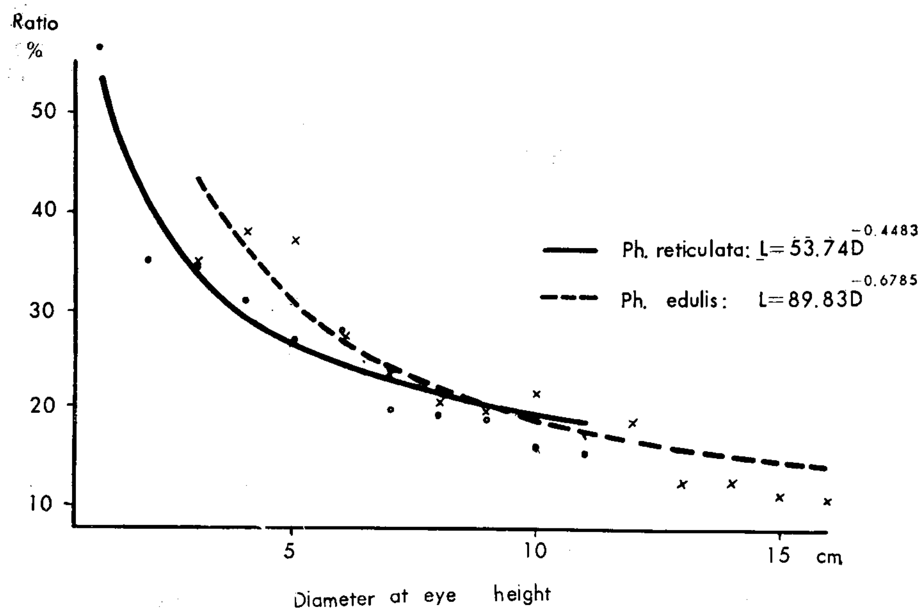
E-3. Clear-length (length of a culm from its base on the ground to the first branch) and weight of a branch with leaves

Clear-length is related to the form of a culm. Bamboo culms with a longer clear-length are generally of better quality. Namely, the higher the clear length ratio (the clear-length to the whole length) is, the lower becomes the tapering grade.

In *Ph. reticulata*, for instance, the clear length ratio varies in the range from 13% to 65% being lower for those bamboos with smaller size culms and higher for those with larger size culms. The ratio is 24–55% in *Ph. edulis*. Comparing with these two species in each diameter grades, the ratio is higher in *Ph. reticulata* than in *Ph. edulis*.

It is natural that the fresh weight of a branch with leaves should be greater in those culms of larger size. The heaviest weight per culm is 7.5 kg in *Ph. reticulata* and 9.2 kg in *Ph. edulis* in Kyoto region. If the ratio of fresh weight of a branch, bearing leaves to the fresh weight of a culm is used as the branch ratio, this ratio is smaller in culms of larger size. The ratio is 15–57% range in the case of *Ph. edulis.* When culms are of the same size, the ratio is lower in the case of *Ph. reticulata* than that of *Ph. edulis* (Fig. 23).

Fig. 23. Relation between the diameter at eye height and the ratio of fresh weight of branches with leaves to the total fresh weight of a culm.



E-4. Leaves

Bamboo leaves fall in a year or a year and a half and give place to new leaves. However, the change takes place simultaneously. Most bamboos, in Japan, change leaves in the period from spring to early summer. The clump forming species of sympodial type in the tropical region such as India, shed their leaves in winter when it is dry and renew the leaves in a short time. Thus bamboos create nutrious elements by assimilation in their leaves all the year round. Therefore the amount of green leaves have an effect on the yield of culms. Table 39-(1) shows the results of the investigation on the number, the surface area and the weight of fresh leaves of a bamboo of the *Phyllostachys* species. *Ph. edulis* has several times as many leaves as *Ph. reticulata* of the same culm size. This is one aspect that shows the vigor of *Ph. edulis*. Further, those species with more leaves and larger total leaf area absorb more water and even in wet soil grow well. Although it is hard to measure the fresh weight of leaves per hectare exactly, we can find the approximate value. It is about 5–10 tons in a grove of *Ph. reticulata* and 10–15 tons of *Ph. edulis* when presumed from the data obtained from other results as those in Table 39–(1). It was found that the fresh weight of total leaves roughly equals the total fresh weight of new culms that develop annually.

Table 39-(1). Number, weight and total area of leaves by culm size

Species	A culm				Leaves		
	Diameter at eye height (cm)	Age (years)	whole length (m)	Fresh-weight (g)	number	area (m^2)	Fresh-weight (g)
phyllostachys reticulata	3.3	2	8.2	2,240	5,369	5.15	798
	3.5	1	7.5	2,220	6,519	6.49	644
	7.0	2	13.4	11,800	8,535	13.47	1,480
	7.2	1	11.9	9,330	8,601	8.00	921
	8.5	1	15.2	17,340	12,362	10.82	1,276
	11.4	3	18.9	34,400	21,401	?	3,721
phyllostachys edulis	4.6	1	9.2	4,510	36,168	12.85	1,205
	5.7	2	10.0	6,450	20,172	13.83	1,344
	5.8	1	9.8	6,100	21,411	16.11	1,987
	9.0	5	15.2	16,450	88,762	63.80	2,300
	12.9	1	15.9	26,800	39,376	19.07	1,252
	14.2	3	20.9	59,530	51,619	35.35	3,357
	14.6	1	20.4	64,300	82,195	32.14	1,900

Remarks; Fresh weight of a culm is excluding those of branches and leaves

Locality: Kyoto, (1954～58)

The proportion of fresh weight of leaves to that of a culm is, in *Ph. reticulata* 10–20% for a culm with a smaller diameter, to 10–15% for a culm with a larger diameter, and in *Ph. edulis*, from 20–30% to 5–10% respectively. That is, the weight of a culm is 5–20 times as heavy as that of leaves. It seems to be a general trend that the greater the number and the weight of leaves is, the larger the culm becomes. Yet the weight of leaves on a culm of a particular diameter grade belonging to the same species varies considerablly. The relation between culm age and the weight of leaves (Table 39-(1)) vary not always in parallel. The relation between the age and the weight of leaves of a mother bamboo and age of rhizome. etc. must be studied further.

When the environmental conditions become unfavorable, the size of leaves in one species tends to become larger and the leaves fall later. A typical phenomenon in this respect is the small regenerated bamboos of the *Ph. reticulata* that appear after flowering. These bamboos bear especially large leaves for a long time.

Table 39-(2). Investigation on a bamboo of *Melocanna bambusoides* in Assam, India

Investigated; Mar., 1959

Age of culm	Leaves		Branches	A culm				Locality
	Number	Fresh weight (kg)	Fresh weight (kg)	Diameter at eye height (kg)	Length (m)	Clear-length (m)	Fresh weight (kg)	
1 year old	683	0. 43	0. 26	5. 6	17. 3	10. 45	11. 3	Patharia Hill
2 years old	594	0. 36	0. 34	5. 5	17. 4	10. 57	9. 0	
3 years old	385	0. 20	0. 40	4. 6	15. 3	9. 81	8. 0	
1 year old	4344	0. 70	0. 70	7. 0	18. 3	9. 37	13. 8	Badshaitala
2 years old	?	1. 10	1. 60	7. 1	19. 4	7. 40	14. 9	
3 years old	1236	0. 50	0. 80	7. 0	17. 2	8. 48	13. 7	

The result of investigation by author on the leaves of *Melocanna bambusoides* in India, is shown in Table 39-(2). It has fewer and lighter leaves of as compared with those of the *Phyllostachys* species of the same size.

3. Flowering and Death of Bamboo and the proper Treatment

A. Interval (Life cycle) of bamboo flowering

Although the bamboo is a perennial plant that propagates asexually, it flowers only after some years, and either sporadically or gregariously. When flowering takes place, these bamboos flower without regard for the age of culms and rhizomes, then die within a few years. However, the new bamboos grown from the rhizome of the flowering bamboos, in the first year after the flowering, generally flower but some do not die.

E. Blatter classified the habit of flowering of bamboo into the following three classes:

(1) Those which flower annually or nearly so.

(2) Those which flower gregariously and periodically.

(3) Those which flower irregulary.

According to the above classification, *Arundinaria* species in India belong to (1) class, *Bambusa* and *Dendrocalamus* species in India, *Phyllostachys* and other genera in Japan to (2) or (3). Flowering of *Ph. edulis* occurs generally sporadically, but other species flower gregariously or sporadically.

a. Single culm forming species of monopodial type

Interval of flowering of single culm forming species in Japan was observed. For example, the interval of flowering of a *Phyllostachys reticulata* grove is over every 60 and probably over every 100 years. That of *Pleioblastus* and *Sasa* grove is over 60 years.

The grove of *Ph. edulis* which has developed from seed sown immediatly after flowering in 1912 at Nakasato-cho in the suburb of Yokohama-city, has not yet flower since, thus 48 years. This pheomenon should be observed until they flower again.

b. Bamboo species of sympodial type

According to P. N. Deogun,[2] some sporadic flowering takes place every year in practically all bamboo areas, but gregarious flowering in one locality occurs only after a long period of years in India.

Interval of flowering of bamboo species in India has been researched by Brandis, Troup, Parker and reported as follows;[1]

Schizostachyum species grove is 30–34 years.

Bambusa arundinacea grove is 30–45 years.

Bambusa polymorpha grove is 55–60 years.
Melocanna bambusoides grove is 10–50 years.
Dendrocalamus strictus grove is 7–70 years.

It seems that the records mentioned above are not sufficient for any definite conclusion, because they did not specified when or where the flowering of bamboos had occured gregariously or sporadically and whether it took place or not in the same grove exactly again.

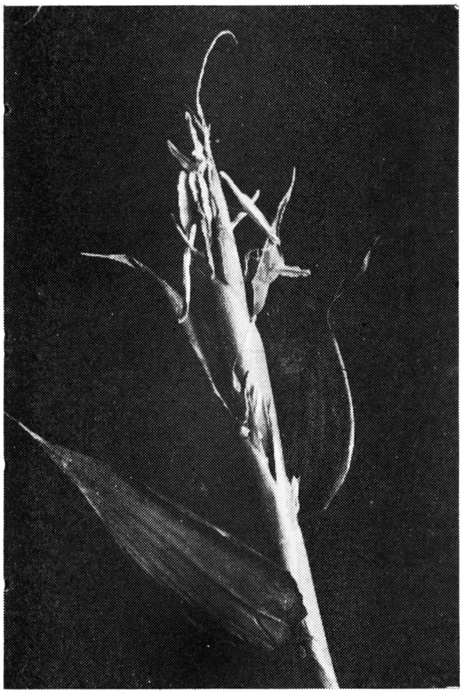


Photo. 28
Flowers of *Phyllcstachys reticulata*
Photo: in Mukomachi, Kyoto. 1956.

Photo. 29
Seed settling of *Pleioblastus chino*
Photo: enlarge, in Chiba pref., 1957. by Tamekuni

B. Causes or Factors of Flowering and Death

Various theories have been presented as for the causes of flowering and death; the influential ones are as follows;

a. Periodicity

Ph. reticulata is said to flower repeatedly as described above, over 60 and probably over every 100 years, but this statement is hard to be confirmed. *Ph. edulis* flowers sporadically quite rarely. The *Sasa* species is said to flower every several decades. The clump-forming species that grow in the tropical regions are reported to flower every 20, 40 or 70 years as shown above, and although the exact length of the period is not known, the frequncy (life cycle) of flowering of them is more than that of *Ph. reticulata*. Considering these all together, one may conclude that the species which bear well-developed seeds flower more frequently than those which bear poor seeds.

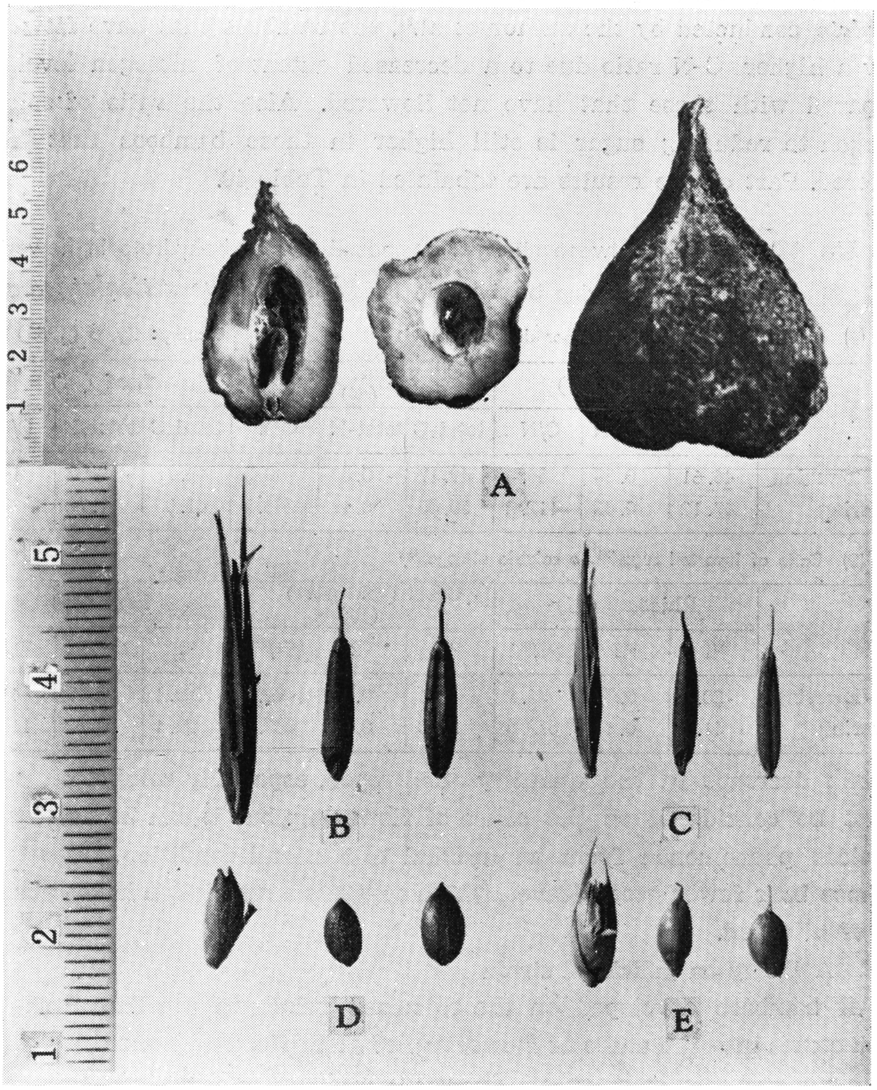


Photo. 30. Spikelets and seeds of bamboo

A. *Melocanna bambusoides*; Weight per 1 grain is 19.0~78.0g
B. *Phyllostachys reticulata*; Weight per 1 grain is 0.04g
C. *Phyllostachys edulis*; Weight per 1 grain is 0.020g
D. *Sasa nipponica*; Weight per 1 grain is 0.025g
E. *Dendrocalamus strictus*: Weight per 1 grain is 0.025g
Scale is marked at 1 cm intervals

b. Damages by insect pests, disease and climate

Damage by insects or diseases should not be considered as the cause of flowering, though it may promote flowering. Further, low temperature and dryness are said to promote it, but no experimental data have been presented.

c. A theory on nutrition

According to the experiments on the C–N ratio of bamboo in a grove of *Ph. reticulata* conducted by the author et al.[3], the bamboos that have flowered show a higher C–N ratio due to a decreased extent of nitrogen level as compared with those that have not flowered. Also the ratio of soluble nitrogen to reducing sugar is still higher in those bamboos that have flowered. Part of the results are tabulated in Table 40.

Table 40. Relation between nitrogen compound and carbohydrate in flowering and nonflowering bamboos in the *phyllostachys reticulata* grove

(1) carbon-nitrogen ratio C/N (per dry matter) Locality: Kyoto (1956)

	Rhizome (%)			Culm (mid part) (%)			Leaf (%)		
	total-C	total-N	C/N	total-C	total-N	C/N	total-C	total-N	C/N
Non flowering	46.61	0.58	80.4	49.17	0.35	140.5	44.77	2.56	17.5
Flowering	47.12	0.42	112.2	50.35	0.17	296.2	41.85	1.77	23.6

(2) Ratio of inverted sugar*1 to soluble nitrogen*2

	Rhizome (%)			Culm (mid part) (%)			Leaf (%)		
	*1	*2	*1/*2	*1	*2	*1/*2	*1	*2	*1/*2
Non flowering	20.8	0.37	56.2	17.6	0.19	92.6	20.1	0.49	41.0
Flowering	41.1	0.11	373.6	24.0	0.04	600.0	22.1	0.20	110.5

The decrease in the quantity of nitrogen, especially soluble nitrogen, cannot be considered as the cause of flowering. but it can be noted as a transient phenomenon from an asexual to a sexual condition. Flowering bamboos bear fewer green leaves, which suggests a restriction in the absorption of nitrogen.

d. A theory on individual strain

All bamboos developed on the rhizomes belong to a rhizome system which comes into the stage of flowering, come to flower at once regardless of their ages or environments. Thus, all the bamboos belong to this group of a rhizome system flower in the same stage, even though rhizomes of the same group are separated and transplanted in different places. Bamboos belong to the group which have different flowering stage do not flower in the same time even though in the same grove.

In short, the bamboo is a perennial plant that has florescence only once in its whole life. When bamboos of a rhizome system reaches maturity, they flower in the whole system. Bamboos usually grow successively by extending their rhizomes. Considering their way of propagation, the rhizome may be considered as the main stem of a tree, and the culms that are developed from the buds on rhizome are equivalent to the branches of the same tree. From this view point, when the rhizomes which in substantial organs reach their maturity for flowering, their all bamboos come to flower.

But, the clump forming species in tropical regions generally flower at shorter intervals than that of *Phyllostachys* species. These phenomena should be studied further.

e. Causes of death of flowering bamboo

The cause of death of a flowering bamboo will be mentioned below. When the time of flowering comes, old leaves fall and instead of new leaves the flowers replace them. Thus, few green leaves are left and the water demand of the bamboo and its upward movement become markedly restricted. This makes the bamboo lose its vigor and finally brings about its death. It is wrong to take the death of a bamboo after flowering for an infectious disease.

However, *Arundinaria wightana* in India, *Shibataea Kumasaca* and the regenerated slender bamboos of *Ph. reticulata* bear many green leaves with flowers and do not die.

C. Regeneration of Bamboo Grove after Flowering.

Such single-culm forming species as the *Phyllostachys* species flower through April into June, and bear seeds in autumn of the same year. The species of sympodial type that grow in the tropical zones, flower from November to February and bear seeds in April and May. Regeneration of bamboo groves after flowering, namely, the development of the bamboos which do not flower in the same grove, is effectuated by the regenerated rhizomes on one hand and by seedlings on the other. The *Melocanna* species regenerate by seedlings that developed from their large seeds (bulbils) after flowering as shown in Photo. 30 and Fig. 25.

The species that produce fertile seeds (the *Sasa*, or a clump-forming species) regenerate by seedlings, (Photo. 30 and Fig. 24-1) while the sterile species such as *Ph. reticulata* that hardly produce complete seeds regenerate by rhizomes. The regeneration of *Ph. reticulata* undergoes the following procedure; Firstly, it develops some short height and slender bamboos such as the *Sasa* after flowering. Then the buds on the basal parts of these culms grow to become rhizomes. These rhizomes produce new culms that do not flower, and gradually new culms of large-size are developed. The procedure is shown in Fig. 24-2.

Fig. 24. Process of the regeneration after flowering

(1) In seedling of *Phyllostachys edulis*

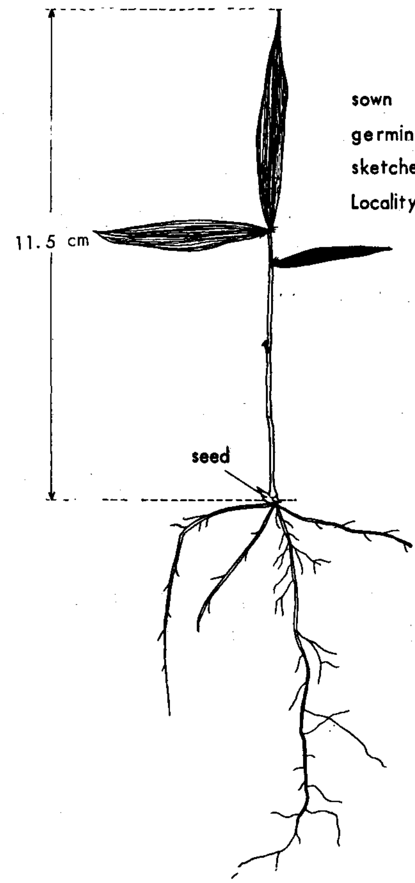
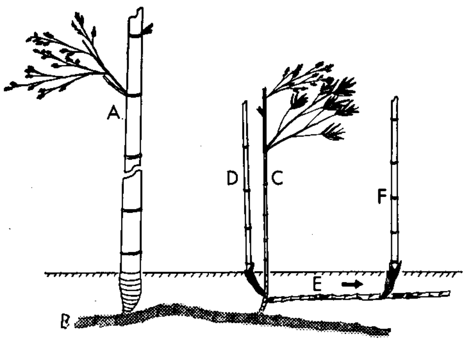


Fig. 24. Process of the regeneration after flowering

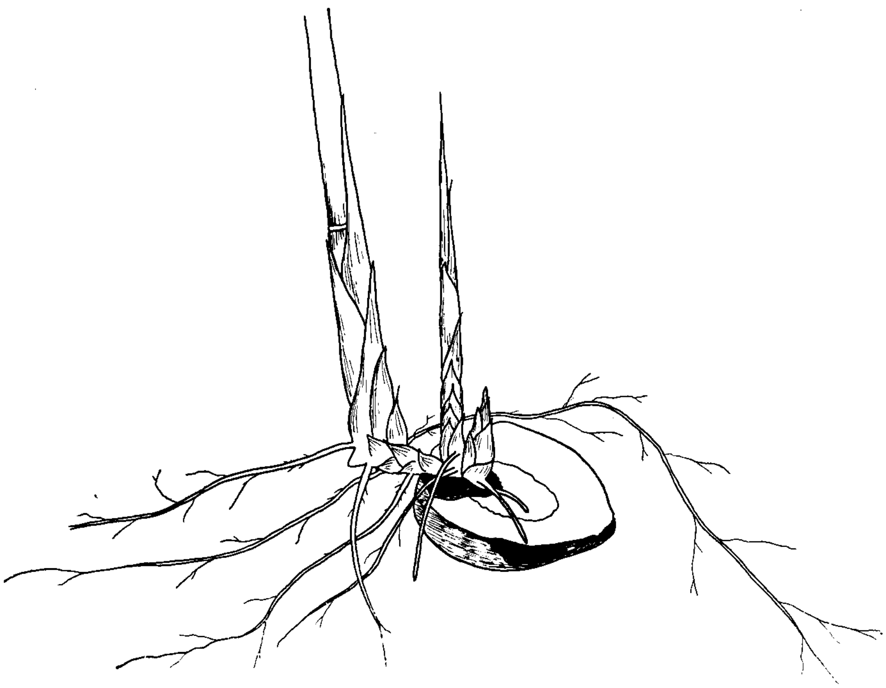
(2) In regenerated rhizome of *Phyllostachys reticulata.*



A, Flowered bamboo in 1954.
B, Rhizome grown in 1950.
Both A and B may die in 1-2 years after flowering.
C, Very Slender new culm grown in 1954 after flowering of A and also it flowers.
D, Slender new culm grown in 1955 from basal part of C and it sometime flowers.
E, New regenerated rhizome grown in 1955 from basal part of C.
F, New regenerated culm grown in 1956 from rhizome E and it will not flower.

Fig. 25. Germinating of *Melocanna bambusoides* seed in Indonesia

Sown at Hagi-city in January 3, 1960.
Investigated, March 15, 1960.
by K. Higasa



D. Proper Treatment of Bamboo Groves after Flowering

Being left neglected after gregarious flowering, it may take about 10 years for the newly grown culms to become as large as the ones before flowering. Therefore proper treatment should be given. The main method of promoting recovery is as follows:

(1) The bamboos that have flowered should be cut and utilized. Yet those which have not flowered, if any, must be left.

(2) Regenerated small bamboos that develop after flowering are the foundation on which grow new bamboos of the next generation that do not flower, and must be left uncut for the following several years.

(3) Mowing of weeds or soil mulching. The soil brought from some other place, it is called " Kyakudo „ in Japanese.

(4) The recovery can be promoted by fertilizing as in C–2 Section, "fertilizer application" of part Ⅱ.

(5) Healthy bamboos should always to be left standing. The bamboos damaged by insects or diseases will promote flowering.

(6) In the case of the clump-forming species, it is more desirable to

transplant the cuttings or to use offset planting immediately, than to sow seeds after florescence. Application of fertilizer has also a great effect.

(7) Efforts must be made to avoid the simultaneous, gregarious flowering of all bamboos. For this, it is important to plant the mixing bamboos selected from different districts where the flowering periods are different. It is not recommendable to leave the grove uncared for after the flowering and death of the bamboos and just to wait for natural recovery. The important thing is to control the flowering of the next generation and to devise some measures for the economical management of a grove.

(8) Even though the bamboos developed after flowering are slender, the over-4-year-old ones should be removed every year or every second year.

The other treatments are as shown in section" thinning method" of Part II.

4. Cytogenetic Studies

Asexual propagation takes place very vigorously in bamboos. However, they flower in certain interval of period as described above. A few fertile seeds are thus produced in the species of *Phyllostachys*, while many sympodial species and *Sasa* species set many fertile seeds.

With the assistance of Yoshikawa and Inamori, Ueda collected pollen grains of *Ph. reticulata* and several other species from flowering[1] and regeneration[2] bamboos, and observed their size, fertility and germination. The pollen grains of *Dendrocalamus strictus* and *Melocanna bambusoides* collected in India were also examined. It has been found that the pollen grains of both Indian and Japanese species show a wide variation in size (Table 41). Namely, the former measures 34.75–57.95 microns in diameter and the latter 49.83–86.40 microns in diameter (Fig 26–a). They vary even within one species. For instance, the pollen grains from regeneration bamboo of *Ph. reticulata* are generally smaller than those of flowering bamboo. The size of pollen grains of regeneration bamboos from several different districts and plots was different as given in Fig. 26–b. In Indian and Japanese bamboos most of the pollen grains had normal nuclei (Fig. 27), but a few abnormal pollen grains with extra nuclei were also observed. In some of the abnormal pollen grains, vegetative and generative nuclei were not distinctly observed (Fig. 27–3, 4). Pollen fertility varied 91.30–97.03% in Indian bamboo species, 90.28–98.62% in Japanese bamboo species and 96.43–97.72% in *Sasa* species.

The germination test of pollen grains of flowering or regeneration bamboo of *Ph. reticulata* was undertaken on sucrose-agar medium (agar 1.5%, sucrose 20% and pH 7.5). The germination percentages of pollen grains were ($26.5 \pm 8.56\%$) and ($25.6 \pm 2.30\%$) and the lengths of pollen tubes grown in 30 minutes were ($44.0 \pm 9.03\mu$) and ($42.5 \pm 8.50\mu$) in flowering bamboo and regeneration bamboo respectively. (Fig. 28–a,b). The germination percentage and the length of pollen tubes of *Ph. reticulata* on agar medium containing gibberellin (250ppm) seemed to be a little higher than on normal medium. (Fig. 28–a, b). It is not clear whether this is due to the effect of gibberellin or not.

1) Flowering bamboo: Bamboo which has reached its flowering period, and dies out eventually.

2) Regeneration bamboo: Slender bamboo which developed subsidiarily from the old rhizome. It flowers also and develops a new rhizome from its base which gives rise to the next generation.

Table 41. Variation table in the size (diameter) of pollen grains (1959)

Species	Indiv. No.	Frequency distribution — size (μ): 14 22 26 29 32 35 38 42 45 48 51 54 58 61 64 67 70 74 77 80 83 86 90 93 96 99 102 106 109 112	Total	Variance	Mean
Melocanna – A – bambusoides (Assam. India)	1	3 2 4 1	10	5.80	42.25 ± 3.62
	2	3 7 10 17 3 1	41	6.28	48.73 ± 3.92
	3	3 7 12 3 4 1	30	5.90	57.75 ± 3.78
	4	2 3 9 5 1	20	5.13	51.38 ± 3.50
	5	6 13 18 50 16 15 12 1 1	132	10.80	41.85 ± 4.53
			233	6.78	48.39 ± 3.87
Melocanna – B – bambusoides (Assam. India)	1	2 4 7 27 9 1	50	4.92	40.75 ± 3.47
	2	3 8 13 43 23 15 5	110	7.63	42.23 ± 4.35
	3	1 3 20 37 16 12 17 2 2 1	111	11.18	43.63 ± 5.58
	4	1 2 8 20 15 2 2	50	4.18	45.44 ± 3.62
	5	1 1 11 7 8 20 1 1	50	7.73	46.65 ± 4.35
			371	7.12	43.74 ± 4.27
Melocanna – C – bambusoides (Assam. India)	1	2 6 17 2 2 1	30	4.68	50.75 ± 3.38
	2	1 1 15 15 15 40 11 2	100	8.53	48.45 ± 4.60
	3	1 18 30 20 15 15 1	100	6.20	34.53 ± 3.91
	4	23 25 23 15 9 1 1 2 1	100	10.05	34.75 ± 4.98
			330	7.37	42.12 ± 4.22
Dendrocalamus – D – strictus (Balaghat. India)	1	1 1 1 5 12 10 5 6 1 1 1 1 1	46	33.17	57.95 ± 10.19
	2	1 1 2 10 26 8 1 1	50	13.98	38.20 ± 5.85
	3	1 1 7 7 16 13 3 2	50	8.83	47.65 ± 4.65
			146	18.66	47.93 ± 6.90
Ph. reticulata – (Madake) (Yasu. Shiga)	1	1 3 7 23 33 55 24 11 1	158	6.29	62.62 ± 4.47
	2	2 2 4 12 29 48 32 12 3 1	145	5.20	62.75 ± 4.06
	3	2 1 3 13 22 32 24 8 3	108	7.34	69.75 ± 4.82
	4	1 6 17 31 49 31 13 2	150	5.72	63.49 ± 4.26
	5	1 2 1 2 5 7 13 22 30 25 12	120	13.50	65.00 ± 5.71
	6	2 5 6 8 20 21 28 10 2	102	10.17	63.69 ± 5.68
	7	1 1 3 3 6 9 20 26 23 8 1	101	11.30	68.69 ± 6.04
			884	8.50	65.14 ± 5.01
Ph. reticulata – A-plot	1	3 3 14 21 29 37 21 4 1	133	7.76	55.06 ± 4.97
	2	1 3 11 29 49 32 9 2 1	137	5.14	67.01 ± 2.28
	3	1 3 7 12 21 22 26 18 11 4 1	126	13.53	68.49 ± 6.56
			396	8.81	63.52 ± 4.60
Ph. reticulata – B-plot (Yasu. Shiga)	1	3 4 9 14 14 13 21 15 10 1	104	14.75	60.34 ± 6.84
	2	1 1 5 4 5 6 9 16 20 15 4 4 1 1	92	22.32	61.01 ± 8.41
	3	1 2 7 21 17 8 10 1 1	68	7.38	66.73 ± 4.62
	4	1 2 4 11 16 21 22 11 5 3 1	97	10.34	64.33 ± 6.91
	5	6 3 6 7 6 6 16 21 19 5 5	100	21.69	60.02 ± 8.29
	6	2 2 5 7 14 28 24 15 6 1 1	105	10.59	64.61 ± 5.50
	7	1 1 1 1 2 6 20 26 30 20 5 4 1	118	11.55	65.23 ± 6.05
			684	14.09	63.18 ± 6.52
Ph. reticulata – C-plot (Yasu. Shiga)	1	2 3 6 20 20 21 25 3	100	7.56	56.8 ± 4.81
	2	1 3 6 10 15 16 20 25 4	100	10.57	56.2 ± 5.69
	3	1 5 6 7 18 20 21 22	100	9.45	55.7 ± 5.39
	4	1 3 4 15 18 27 29 3	100	5.33	57.6 ± 4.49
			400	8.25	56.6 ± 5.10
Ph. reticulata – D-plot (Yasu. Shiga)	1	1 1 2 6 15 21 25 14 10 3 2	100	11.12	65.9 ± 5.89
	2	3 11 14 20 25 16 7 2 1 1	100	9.79	61.5 ± 5.57
	3	3 8 18 22 27 16 4 2	100	7.21	61.9 ± 4.78
	4	2 11 20 22 27 14 3 1	100	6.59	61.4 ± 4.57
			400	8.68	62.7 ± 5.20
Ph. reticulata – (Ōharano. Kyoto)	1	1 16 12 14 15 14 22 5 1	100	12.39	55.4 ± 5.89
	2	2 10 11 16 8 13 17 13 8 2	100	33.32	51.2 ± 9.95
	3	4 14 12 13 17 20 13 4 2 1	100	13.21	59.9 ± 6.47
	4	2 10 12 13 15 16 18 7 6 1	100	14.67	61.2 ± 6.82
			400	18.40	56.9 ± 7.33
Ph. reticulata (Ōharano. Kyoto)	1	1 3 3 19 19 21 19 19 23 20 16 9 7 3 1	193	9.13	69.12 ± 11.21
Ph. reticulata – (Exp. For. st. Kyoto. Univ)	1	4 5 8 13 14 28 20 16 13 7 2 3	133	18.44	58.51 ± 7.62
	2	1 2 3 12 11 16 20 25 17 11 5 3 1 1 1	129	19.29	65.14 ± 7.83
	3	1 8 9 9 11 6 4 7 4	59	17.02	60.56 ± 7.28
	4	1 2 3 4 6 12 13 14 15 18 17 12 6 1	124	24.05	72.52 ± 8.79
			445	19.70	64.16 ± 7.88
Pl. gramineus – (Taimimchiku) (Exp. For. st. Kyoto Univ)	1	2 17 53 89 84 49 38 24 6 2	364	9.2	47.8 ± 5.43
	2	2 33 71 84 67 37 19 11 4 1	329	8.5	46.0 ± 5.11
	3	2 17 29 34 25 8 2 1	118	5.6	44.3 ± 4.20
			811	7.8	46.0 ± 1.88
Si. Kumasaca – Nakai (Okamesasa) (Kibune. Sakyo. Kyoto)	1	1 3 7 13 17 21 19 19 8 8 5 3 1 3 2	130	28.91	86.40 ± 9.58
	2	1 2 3 10 9 12 14 19 21 14 7 2 3 1 1 2	121	25.45	79.52 ± 8.99
	3	2 3 7 12 8 12 12 21 16 9 7 9 4 2 2 1	127	31.39	82.25 ± 9.99
			378	28.58	82.78 ± 9.52
Pl. Simoni Nakai (medake)	1	1 9 18 24 28 26 25 15 13 2	161	4.12	49.83 ± 6.41
Si. tootsik Mak. f. – albo-stricta Muroi (Suzukonarihira)	1	2 4 12 22 32 24 14	110	6.35	50.79 ± 4.49
	2	4 12 22 30 26 14	110	6.05	51.26 ± 4.38
	3	2 4 14 22 14 10	66	5.02	51.49 ± 3.97
			286	5.81	51.18 ± 4.28

Fig. 26-a Variation in size of pollen grains

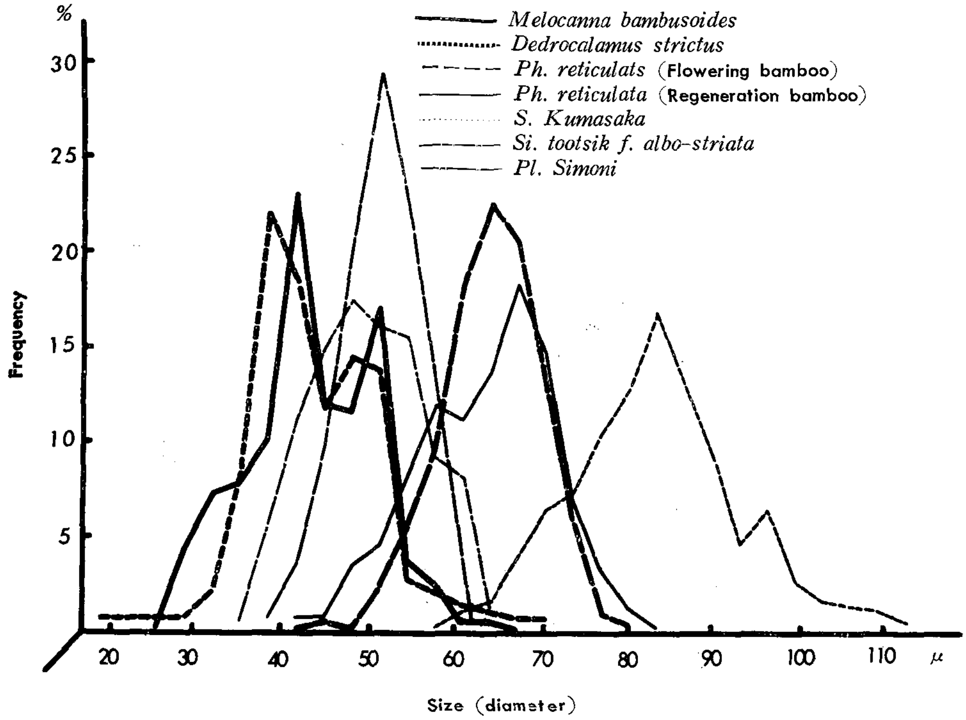


Fig. 26-b Variation in size of pollen grains of *Ph.reticulata* (regeneration bamboo)

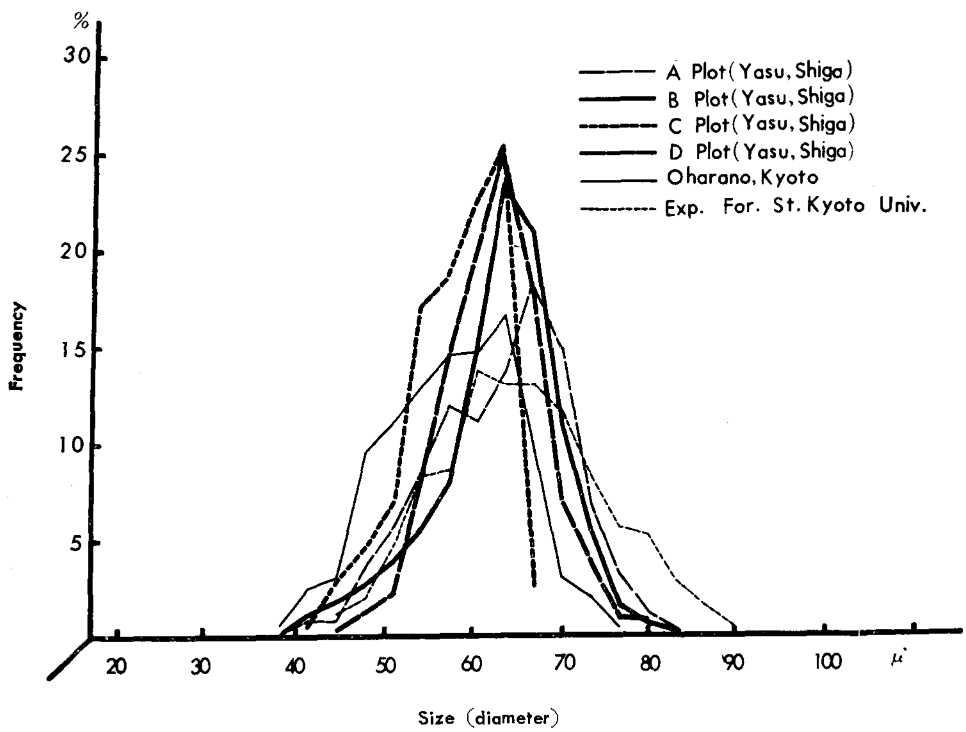
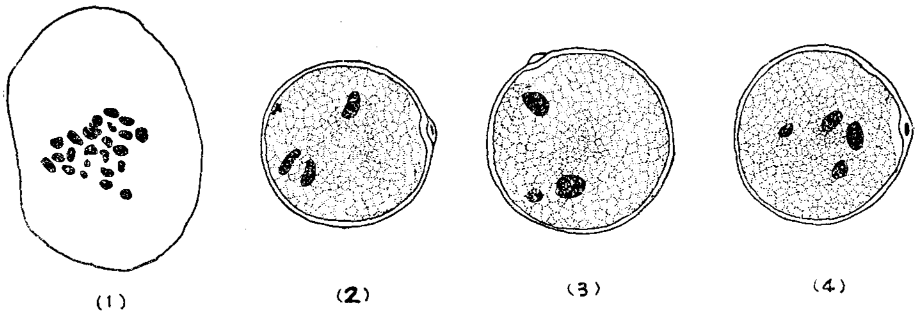


Fig. 27. PMC at metaphase I, and pollen grains of *Phyllostachys reticulata*



(1) Polar view of the first meiotic metaphase showing 24 bivalent chromosomes (after Uchikawa 1933).

(2) Normal pollen grain with 1 vegetative and 2 generative nuclei.

(3, 4) Abnormal pollen grains resulted from irregular meiotic division.

Fig. 28-a Pollen germination on agar media

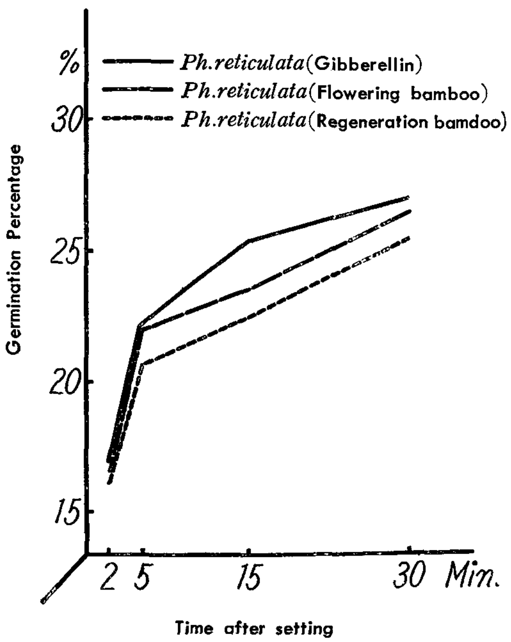


Fig. 28-b pollen tube growth on agar media

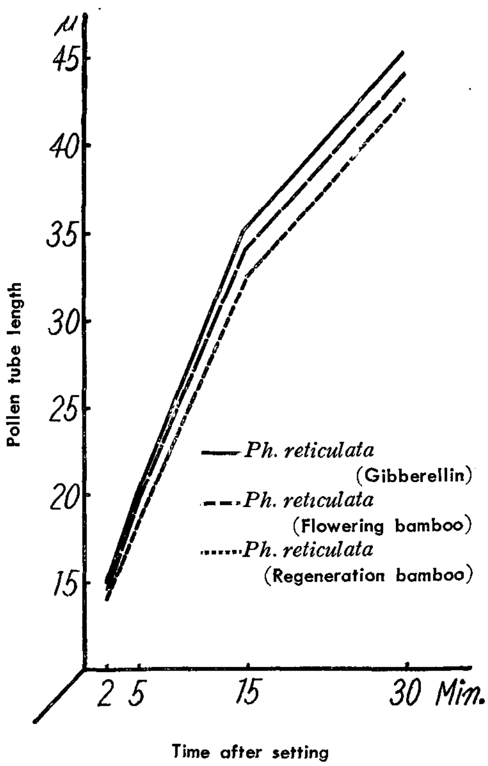


Table 42. List of chromosome numbers of Bambuseae

(C. D. Darlington and A. P. Wylie, 1955)

Material	Chromosome number	Author	Year	Country
Arundinaria (Sasaella)				
iwatekensis	48	Uchikawa	1935	Japan
simonii	48	Parodi	1946	China
Chimonobambusa				
marmorea	48	Uchikawa	1933	China
Indocalamus				
wightianus Nilgiri Bamboo	48	E. K. J. *		India
phyllostachys				
aurea Golden B. & 4 spp.	48	Uchikawa	1935	China, Japan
striata	48	Uchikawa	1943	Japan
	{ 48	Uchikawa	1943	Japan
marliacea	{ C. 72	Audulov	1928	〃
flexuosa	54?	Hunter	1934	China
pleioblastus (Arundinaria)				
fortunei	48	Hunter	1934	Japan
gramineus	48	Uchikawa	1935	〃
pleioblastus (Arundinaria)				
chino (maxinowiczii)	48	Tateoka	1954	China
simonii Silverstripe B.	48	Uchikawa	1933	China
pygmaeus	54?	Hunter	1934	Japan
pseudosasa				
Japonica Arrow B.	48	Uchikawa' E. K. J. *	1935	Japan
Sasa				
Sp. (3x)	36	Uchikawa	1943	Japan
Kozasa	48	Yamaura	1933	
Sasamorpha				
purpurascens (borealis)	48	Tateoka	1954	Japan
Semiarundinaria				
yashadake	48	Uchikawa	1935	Japan
Sinobambusa				
tootsik	48	Uchikawa	1933	Japan
Tetragonocalamus (chimonobambusa)				
angulatus	48	Uchikawa	1935	China
Bambusa				
bambos Common B.	{ 72	Janaki Ammal	1938	E. Indies
	{ 70	parthasarathy	1946	
floribunda	72	Uchikawa	1935	Java
multiplex Henge B.	72	Uchikawa	1935	Trop. Asia
as nana	72	Yamaura	1933	Japan
polymorpha	72	E. K. J. *		Burma
vulgaris Feather B.	72	E. K. J. *		Trop. Asia
Dendrocalamus		Richharia & K.'	1940	
strictus Male B.	{ 72 { 70	Parthasarathy	1946	India, Java
Ochlandra				
scriptoria	c. 72	E. K. J. *		India
travancoria	c. 72	E. K. J. *		S. India

*Dr. E. K. Janaki-Ammal

The seeds of *Ph. reticulata* (madake) and *Ph. edulis* (mōsōchiku) from Japan and *Bambusa arundinacea* from India were subjected to X-rays. A few seeds of Japanese species irradiated at 10,000r germinated, but the seeds irradiated at 20,000r did not (Photo. 33). Two hundred seeds of *Bambusa arundinacea* irradiated at 18,000r germinated, but the percentage of germination (12%) was very low.

A few seeds of *Ph. reticulata* (madake) and *Ph, edulis* (mōsōchiku) were treated by 0.2% colchicine. In this experiment the seedlings showed normal growth (Photo. 31-c). Consequently, hundred seeds of *Bambusa arundinacea* were treated by dropping method with 0.2% and 0.4% colchicine for 48 hours. The germination percentage was very low.

The pollination experiment was made among the flowering or regeneration bamboo of *Ph. reticulata* in Ōharano, Kyoto. But only shrivelled seeds were obtained (Photo. 31-b).

The chromosome numbers of bamboo species are listed in Table 42. Most of the Japanese species and varieties of bamboo of monopodial type have 36 or 48, while most of the tropical species and varieties of bamboo of sympodial type have 72. They are thought to be 3*x*, 4*x* and 6*x* with the basic number of 12. The diploid species is not known as yet. We have an expectation to find it perhaps somewhere in the tropical region. For this reason, we are eager to collect more materials from Formosa Burma, Cambodia, Thailand, Laos, Philippines and South southern China.

References

(1) E. Bllater, The flowering of bamboos. Journal, Bombay National Hist Society, Vol XXXIV, 1930.

(2) P. N. Deogun Indian Forest Vol. II, No. 4, 1940.

(3) Transaction. Jap. Forest. Soc. No. 67, Apr., 1957.

(4) Tropical Silviculture Vol. I. II. F. A. D. 1957.

Photo. 31-a. Pollination practice of *Pyllostachys reticulata* (Madake)

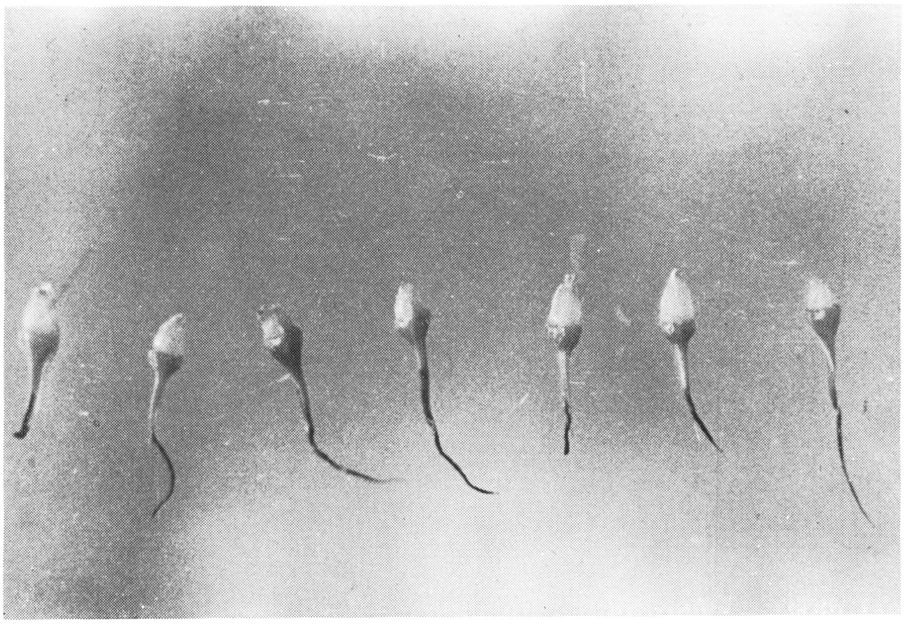


Photo. 31-b. Seeds obtained by artificial pollination (shriveled seeds) (Magnification, x ca. 5)

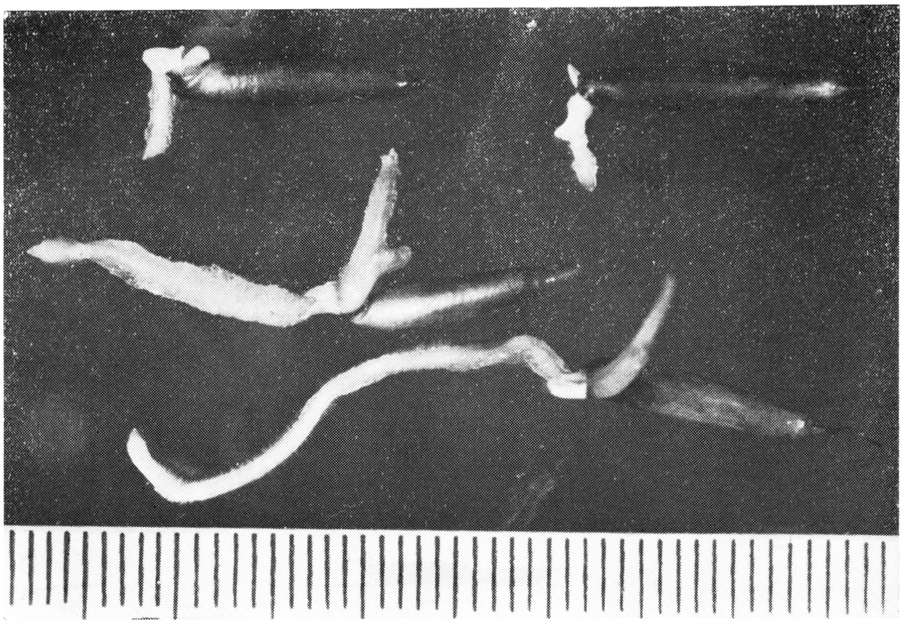


Photo. 31-c. Germinating seeds of *Phyllostachys reticulata* after colchicine treatment (A scale is divided at 1 mm intervals.)

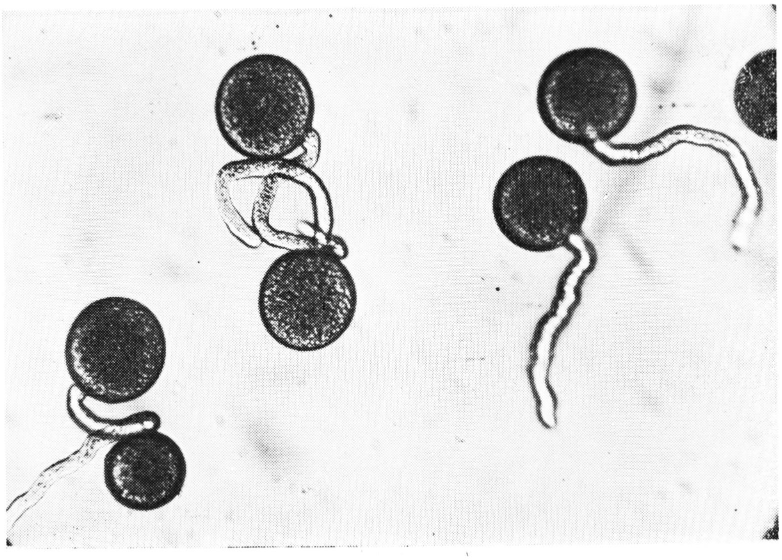
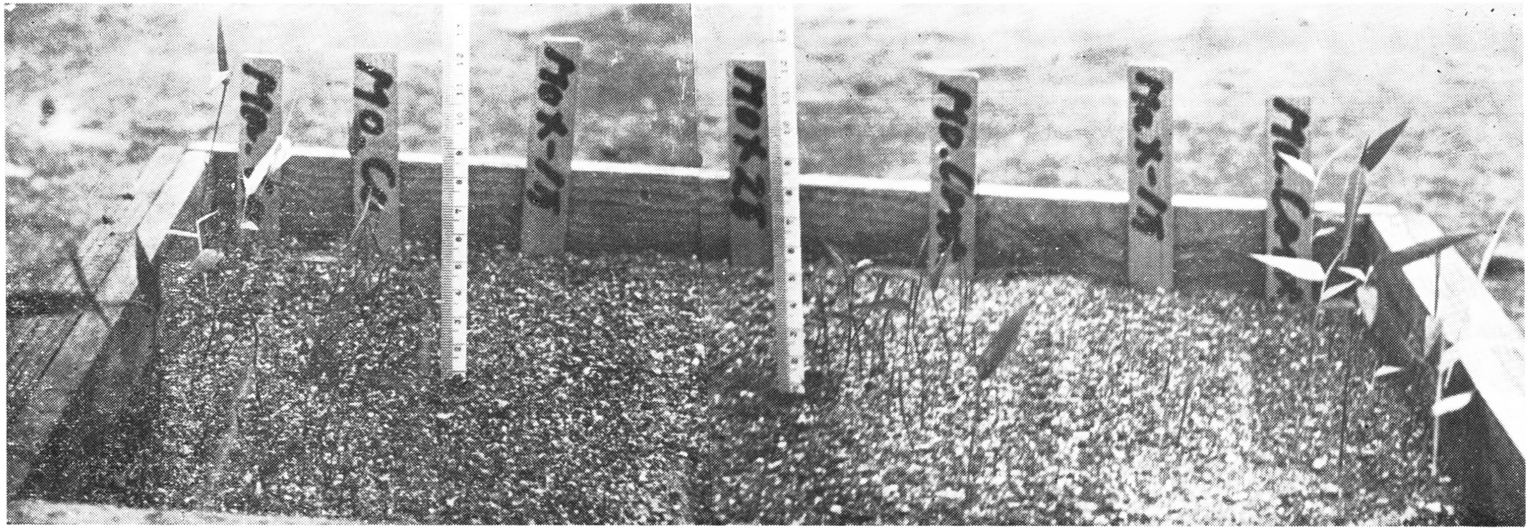


Photo. 32. Germinating pollen grains on agar medium of *Ph. reticulata* (Magnificaiion, x ca. 900)

Photo. 33. X-rayed (3rd, 4th and 6th rows from left) and colchicine treated (1st and 2nd rows) seedlings of *Phyllostachys reticulata* (Madake) and *Phyllostachys edulis* (Mosochiku). Control 5th and 7th rows.



Madake: Colchicine treated (0. 2 %)

Mosochiku: Colchicine treated (0. 2 %)

Mosochiku: X-rayed (10, 000r)

Mosochiku: X-rayed (20, 000r)

Mosochiku: Control

Madake: X-rayed (10, 000r)

Madake: Control

II. APPLICATION

1. Characteristics for Management of Bamboo Grove and Importance of its Utilization

A. Characteristics for Management

a. Yearly increment of culms and its increment percentage

The increment of standing stock in a bamboo grove refers to the total number of new culms produced every year, which grow into full size within the year and do not grow further growth thereafter. As for the volume of bamboo culms, it is commonly expressed in Japan by the term *soku* (bundle). On the other hand, the relation of the actual volume, excluding hollow part of internode, and the fresh weight of a culm will be shown in the following table. Each numeral shows the average gained from the volumes examined.

Table 43. The relation of actual volume and fresh weight

	Ph. reticulata	*Ph. edulis*
Actual volume (1m³)	30 *soku*	33 *soku*
Fresh weight per m³	1, 050 kg.	1, 050 kg.
Fresh weight per *soku*	35 kg.	32 kg.

Remark: The number of culms per one *soku* is as shown in Table 36—(3)

Table 44. Annual increment of culms and its percentage of standing stock in Japanese bamboo grove

Species (grove)	Site-grade	Annual increment of culms (A) (= annual yield)				Standing stock (B) (= total culms)			(A)/(B)
		Number	Volume (*soku*)	Actual volume (m³)	Fresh weight (ton)	Number	Actual volume (m³)	Fresh weight (ton)	(%)
Phyllostachys reticulata	good	1, 200>	400<	13<	14<	8, 000>	89<	93<	20
	ordinary	2, 000	250	8	8	12, 000	50	53	20
	poor	2, 000<	150>	5>	5>	15, 000<	38>	39>	20
Phyllostachys edulis	good	500>	600<	18<	19<	4, 000>	145<	154<	10-15
	ordinary	800	400	12	13	6, 000	90	96	10-15
	poor	1, 000<	200>	6>	6>	8, 000<	48>	51>	10-15

Remark; 1 *soku*, 35kg. (*Ph. reticulata*)
32kg. (*Ph. edulis*)

The yearly increment of culms (total increments of new culms) in each hectare is as shown in the above Table 44. It is 5–13 m^3 or over (about 5~14 tons or over) in groves of *Ph. reticulata,* and 6–18 m^3 or over (about 6–19 tons or over) in those of *Ph. edulis.* This increment is almost as good as that of a tree forest. Even in the sites of lower quality (poor soil), the yearly increment can be raised by the improving treatments, such as fertilization.

For the species of sympodial type which grow in the tropical region, the increment is as shown in the following Table 45. The increment in any of them is lower compared with those in the grove of *Phyllostachys* in Japan. This implies that the increment can be raised by an intensive treatment.

Table 45. Annual increment of culms in Indian bamboo grove (average)

	Number of new culms produced per year		Air dry weight	Air dry weight
Species (grove)	per clump	per ha	per culm	per ha
			(kg)	(ton)
Dendrocalamvs strictus	4	800	3.5	2.8
Bambusa arundinacea	3	500	10.0	5.0
Melocanna bambusoides	—	1,000	5.0	5.0

Investigated, from Feb. to Mar. 1959.

b. Yield

In their groves, bamboos can be harvested yearly as soon as they reach the cutting age, for new culms produce every year. Namely, the most part of the yearly increment shown in A–1 of part II becomes the yield. It is one of the features of bamboos that a yield can be expected every year.

In the species of sympodial type, the yearly yield is equal to the yearly production of new culms which is shown in the preceding section. But the amount of yield varies acccording to the number of years in the felling cycle. In case of a three-year-cycle, the yield is about three times as much as the amount of yearly new culms. In this case, it means that no yield can be obtained for two years.

c. Cutting age

The cutting age of a bamboo is very young unlike other trees. In the *Phyllostachys* species, for instance, the suitable cutting age is about four years. Moreover, since bamboos do not thicken at all from the second year on, the cutting age does not change even in poor soil. In managing a bamboo grove, it is important for obtaining a large yield to cut every year those that have attained the cutting age. If the old bamboos are left standing, the productive power is necessarily diminished.

In the clump-forming species of sympodial type, cutting must be repeated by age rotation. The shorter the year-cycle is, the better it is for a bamboo grove.

Detailed explanation on the cutting age together with the yield will be presented in Section D.

d. Unit area for management

A bamboo grove can be managed even within small cultivating area, for the cutting age of the bamboo is only a few years.

In a grove of the *Ph. reticulata*, for instance, 900 kg of culms and 20–40 kg of culm sheaths, on an average, are harvested from only 0.1 ha. that bring several thousand *yen* in Japanese coin as net income. Therefore even a grove of 0.1 ha. can be the object of a side income source for farmers in Japan.

e. Production cost

Even if the thinning in bamboo grove is carried out, new culms are produced asexually by mother bamboos and rhizomes. Thus the new planting of bamboos every year after harvest is not necessary. Therefore the planting cost is saved. A proper cutting means a plantation. Also the cost of weeding may be saved. What the income brings by cutting alone is to the advantage of a bamboo plantation and should not be overlooked from the standpoint of limited labor. If a grove is under careful operation, being from supplied with fertilizers for instance, greater harvest can be expected.

B. Importance of utilizing Bamboo Groves

a. Utility as resources

Bamboos, having many uses, are indispensable in our daily life. Those culms used in Japan, are ca. 200,000 tons a year, according to records. As bamboo articles are hand made, rural villages are raising their income. More than 80,000 tons of bamboo sprouts are used as food. Bamboo goods, such as bamboo blinds, cages, fishing rods, poles, slide-rules, etc. are exported, the amount in this case being 30,000 tons in terms of culm weight. Yet this is insufficient for its utility. A further development of the use in the line of pulp industry, which consumes a large amount of culms, is hoped. At the moment, bamboo paper of superior quality is being produced at the Nittô Paper Mill Company. Currently 20,000 tons of culms are being consumed yearly in industries; a further increase in the use of culms for paper production is expected.

Photo. 34. Digging out of the edible sprout of *Ph. edulis* on April 25, 1960 in Mukomachi, Kyoto

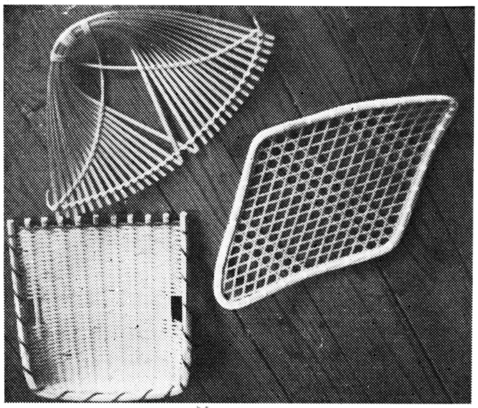


Photo. 35. Products made by bamboo in Kyoto-district

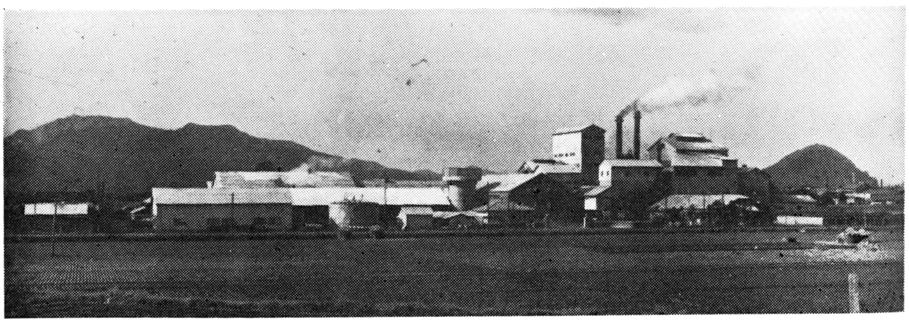


Photo. 36. Nitto Bamboo Paper Mill in Hagi, Yamaguchi-Pref.

The utility of the bamboo for production of paper not only covers the lack of timber as material, but also plays an important role in improving the bamboo grove and increasing the production of culms further in aid of the farm economy. It has already been mentioned in the previous descriptions that new culms of many different sizes are produced every year in any bamboo groves. Yet it is a general trend that only the large-size culms of good quality are cut for manufacturing uses, leaving small-size culms of inferior quality. This has been the result in increasing the number of culms of inferior quality in the groves, by degrading their productivity. Therefore, culms of inferior quality also must always be removed by cutting in order to increase the yield of those culms of good quality. It is a big advantage that the pulp industry can utilize even bamboos of inferior quality. An annual production of over 100,000 tons of pulp may be expected in Japan if over 400,000 tons of bamboo culms can be produced.

b. Role in the petty farmer's economy

The total surface area of tree forest in Japan is 25 million ha. including 14 million ha. of private forests. 95 % of these private forests are smaller than 5 ha. per owner and those with less than 1 ha. are 70 %. Therefore this suggests that the majority of owners are small-holders. Moreover, because many of the groves are mountainous and the soil is poor, the owners find it hard to produce a satisfactory yearly income. It is very important for a number of small farmers to secure a additional yearly income from a small area by a more efficient management of bamboo groves. The total surface area of bamboo groves is reported to be 170,000 ha. in Japan. Though this is not large, it shows that the majority of farming families of several million seem to have their own bamboo groves no matter how small they are. Therefore, an attempt to increase the income by improving the management of bamboo groves has a great importance in enriching the economic life of rural areas. The market value of the bamboo can be raised by cooperative marketing; hence the importance of direction and guidance for improving the management of bamboo groves must be recognized.

c. Role in conservation of land

The bamboo grove not only secures the economical production but also plays an important role in preventing the soil from erosion. Unfortunately the latter aspect tends often to be neglected.

The bamboo groves on the riverside serve a great deal in the defense against floods, and those in mountainous districts prevent the soil from such erosion[1] as landslides; and further they prevent breakwaters on the coast from destruction. These practical side effects were recognized through the investigations made after the typhoon damages[2]. The following reasons may be presented as responsible for these effects.

(1) The bamboos that always are densely standing in a great number slow down the speed of flow. This function which prevents floods becomes more effective if the bamboo groves are thinned out properly every year. It is advantageous to prevent floods on one hand, and to keep on an economical production on the other. The bamboos, at least over 10,000 culms per ha. stand on strongly extended roots and have a cooperative power. The action of slowing down the speed of running water in the bamboo groves protects the levees from collapse in case the dashing water overflows. They further serve in improving deserted lands by their effective function of stagnating water temporarily. Even though culms fall on to the ground, and are covered with the soil, new sprouts will grow the next spring and become mature culms; then the grove will regain its preventive force. This is a unique function of a bamboo grove (photo. 39, 40).

The author and Prof. H. Ishizaki have examined on the strength of a standing bamboo (P) of the *Ph. reticulata* grove in Kyoto. The experiments have revealed that it is proportional to the third power of circumference; an equation reads; $P = \alpha D^3$

Photo. 37. A grove of bamboo (*Ph. reticulata*) planted for riverside defence against a flood at Ado-river, Shiga-Pref.

Photo. 38. The bamboo (*Ph. reticulata*) grove protects against the flood of a river. The place where no bamboos were planted on the riverside was broken by flood. (Ado-river, Shiga-Pref. in 1953)

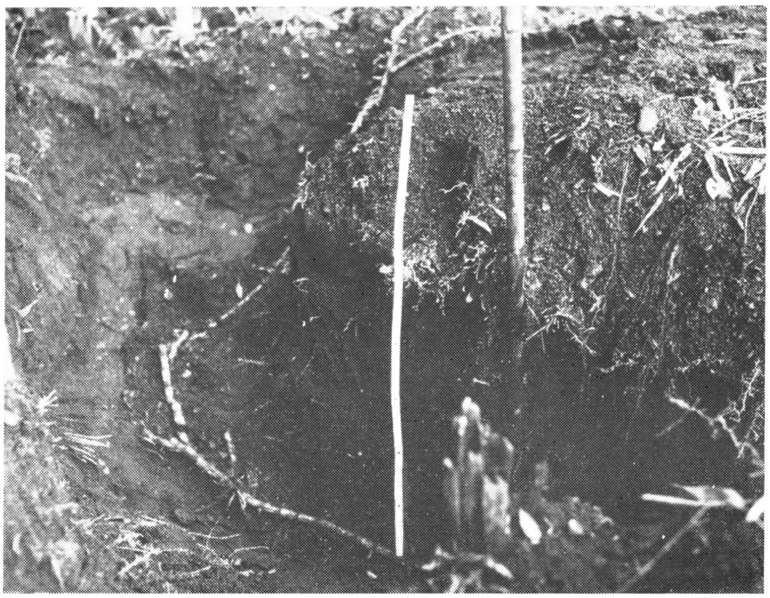


Photo. 39. The rhizome of *Ph. reticulata* is buried at the depth of 1 m by flood, still this rhizome is reproductive and grown up to near the ground, at Ado-river side, Shiga-Pref. in 1953.

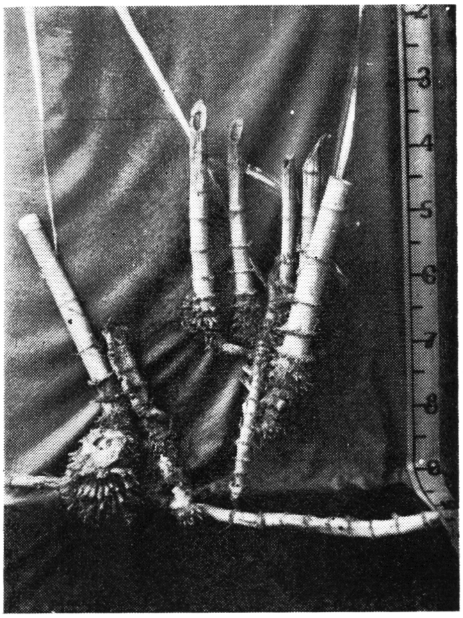
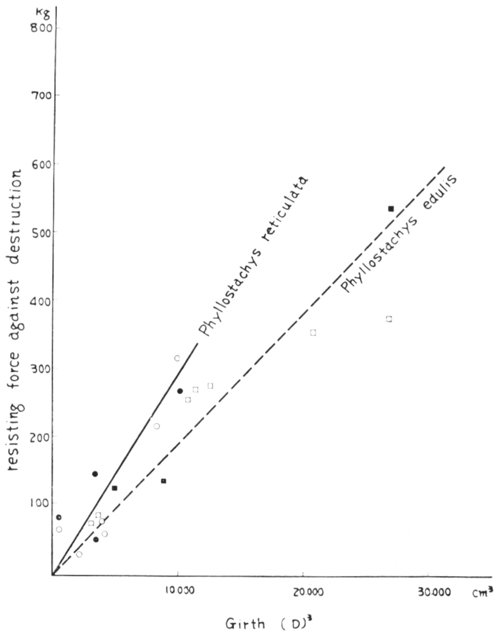


Photo. 40. Abnormal case of monopodial type; clump formation in the *Ph. reticulata* grove. *Ph. reticulata* which was deeply buried under the ground by flood has developed new culms closely from the basal part of mother culm, at Ado-river side, Shiga-Pref. in 1953. Scale is marked at 10 cm intervals.

Fig. 29. Relation between resisting force against destruction and cube of girth.
Introduced from $P = \alpha D^3$
Locality: Fushimi, kyoto year: 1955



Among the erect bamboos of the same size, strength(P) of *Ph. reticulata* is 1.6 times as strong as the *Ph. edulis*. However, *Ph. edulis* is not always considered weak because it produces large-size culms. For example, it was found by tests that one bamboo of *Ph. reticulata* with 3–8 cm in diameter at eye height can resist a horizontal force of 50–300 kg while that of *Ph. edulis* with 5–11 cm in diameter can stand 100–700 kg (Fig. 29). In addition, it was found that the 3–4-year-old normal bamboos of two species mentioned above are stronger than the older ones. The resisting force against destruction was tested by pulling two erect bamboos of each kind together. Their strength together was proved to be more than twice that of the resisting power of a single bamboo.

(2) Concerning the ground; the branched and connected rhizomes serve as a kind of network, like a bamboo reinforced concrete to prevent the soil from erosion or landsildes. Rhizomes and roots grow in the soil almost as deep as one meter. The total length of rhizomes per ha. is as long as 20 km or more, and they serve as a strong network, crisscrossing one another.

As shown in the above, treating bamboo groves so as to keep them always in excellent condition, will increase their resistance against floods. This defending force will be lessened if a good management of bamboo grove is neglected.

d. Other practical uses

Bamboos may be utilized for the purposes such as decoration plants in a garden or a park, and also they may be used as a safety spot at times of earthquakes. Further, its pliancy, rigidness or elegant form particular to the bamboos is utilized in designs, patterns etc.

Reference; [1] Dr. K. Ueda: Forest for Preventing Floods. Apr., 1955. [2] ibid.

C. Comparison with Management of Tree Forests

As for the management of tree forests and bamboo groves, there are some different characters as listed below, and it is not easy to define which management is more profitable from an economical point of view.

This comparison suggests that it is desirable for farmers to manage both kinds of forests of a proper area. Yet in some cases, the bamboos and their rhizomes were entirely removed and other new trees were planted in the same place. From this point of view, the economy should be calculated for the two as shown in Table 46. The table represents the balance sheets for Kyoto district where bamboo groves are managed intensively and for Kyushu district where they are managed extensively.

Comparison with the feature of tree forest and bamboo grove

Item	Tree forest	Bamboo grove
Growth	A single individual thickens annually.	A single individual completes its culm size within several months after appearance on the ground.
Volume of annual growth (per ha.)	Total increments of individual per ha are 3-30 cubic meters.	Total volume of annual new culms are 3-30 cubic meters per ha.
Propagation	Artificial or natural regeneration.	Mainly propagate asexually.
Cutting age	Long (over several decades).	Short (several years).
Yearly growth per cent	2-5%.	10-30%.
Weight (fresh) of single log	Heavy (over 300 kg).	Light (below 60 kg.).
Yield	Harvested after accumulation of annual increments.	Productivity is higher if culms are harvested annually by cutting (the amount of yield is equivalent to the annual increment).

Table 46. Comparison with the management of *Ph. reticulata* grove and *Cryptomeria Japonica* forest

(1-A) A balance sheet on rather intensive management of *Ph. reticulata* grove in Kyoto (per ha.)

		Number	Unit price (yen)	Amount (yen)	Future value (after 40 years) (yen)	Note
Expenditure	Fertilizer			16,000		Ammonium sulfate, superphoshate of lime, potassium chloride.
	Fertilizing, weeding, etc.	30 (persons)	500	15,000		
	Collecting culms sheaths	15 (persons)	500	7,500		
	Digging and collecting sprouts	4 (persons)	500	2,000		Edible sprouts.
	Baskets for harvest	40		2,000		
	Cutting	23 (persons)	500	11,500		Inclusive of the expenses for carrying out 15 *soku* per person to road side administrative cost.
	Miscellaneous			2,000		
	Total			56,000	8,666,747	Rate of interest; 6% compound interest of 40 years.
Income	Culms	350 (*soku*) 12,300kg.	300	105,000		
	Sprouts	750 (kg.)	16	12,000		
	Culm sheaths	260 (kg.)	90	23,400		
	Total			140,400	21,728,772	Yearly harvest compound interest of 40 years.
Margin				84,400	13,062,025	Rate of interest: 6%.

Table 46. (1-B) A balance sheet on the management of *Cryptomeria Japonica* forest

(the case of *C. Japonica* planting after clear cutting of the bamboo grove: 1-A table) (per ha.)

		Number	Unit price (yen)	Amount (yen)	Future value (after 40 years) (yen)	Note
Expenditure	Clear cutting of culms for preparation of planting trees	80 (persons)	500	40,000	1,172,570	Clear cutting every bamboos for afforestation of trees, bundling 15 *soku* per person, carrying to road side.
	Soil preparation	80 (persons)	500	40,000		Digging up the rhizomes.
	Seedlings	4,000	6	24,000		Inclusive of carrying cost to planting place.
	Planting	20 (persons)	500	10,000		
	Seedlings for after-planting	400	7	2,800		
	Planting seedlings for after-planting	2 (persons)	500	1,000	36,873	
	Fire insurance			1,000	10,286	Payment on 1st year.
	Weeding	110 (persons)	500	55,000	448,101	Practice in intervals of 2, 3, 4, 5, 6 and 10 years after planting.
	Removal of vines, improvement cutting	30 (persons)	500	15,000	72,335	Practice at 10 and 15 years after planting.
	Total			188,800	1,740,165	Rate of interest: 6% compound interest of 40 years.
Income	Bamboo culms	900 (*soku*) 31,500kg	300	270,000	3,404,567	Good culms by clear cutting.
	Bamboo culms	300 (*soku*) 10,500kg	150	45,000		Slender culms by clear cutting. Culms are yielded only in this generation.
	Subsidy for afforestation			16,000		
	Yield in thinning	140 (m^3)	3,500	490,000	1,174,334	Standing trees, 20-30 years after planting.
	Final cutting	450 (m^3)	5,700	2,565,000	2,565,000	Standing trees, 40 years after planting.
	Total			3,386,000	7,143,901	Rate of interest: 6% compound interest in 40 years.
Margin				3,197,200	5,403,736	

Table 46.

(2-A) A balance sheet on rather extensive management of *Ph. reticulata* grove in Kumamoto, Kyushu region (per ha.)

		Number	Unit price (yen)	Amount (yen)	Future value (after 35 years) (yen)	Note
Expenditure	Cutting	16 (persons)	350	5, 600		No fertilizing, bundling 15 *soku* per person, carrying out to road side.
	Collecting culm sheaths	10 (persons)	350	3, 500		
	Administrative cost			1, 000		
	Total			10, 100	1, 125, 494	Rate of interest: 6%.
Income	Culms	300 (*soku*)	80	24, 000		Relivery at road side.
	Culm sheaths	10, 500kg 180 (kg)	80	14, 400		About 190 kg.
	Total			38, 400	4, 279, 104	Rate of interest: 6% yearly harvest compound interest of 35 years.
Margin				28, 300	3, 153, 610	

Remark: Culms are carried to road side by owners work.

Table 46. (2-B) A balance sheet on the management of *Cryptomeria Japonica* forest

(the case of the *C. Japonica* planting after clear cutting of the bamboo grove: 2-A table) (per ha.)

		Number	Unit price (yen)	Amount (yen)	Future value (after 40 years) (yen)	Note
Expenditure	Clear cutting of culms for preparation of planting trees	54 (persons)	350	18, 900	516, 122	Clear cutting for afforestation, bundling 15 *soku* per person, carrying out to road side.
	Soil preparation	80 (persons)	350	28, 000		Digging up the rhizomes
	Seedlings	3, 000	5	15, 000		Carrying out to planting site.
	Planting	15 (persons)	350	5, 250		
	seedlings for after-planting	300	6	1, 800		
	Planting seedlings for after-planting	2 (persons)	350	700	18, 128	
	Fire insurance			1, 000	7, 686	
	Weeding	100 (persons)	350	35, 000	213, 083	Practice in intervals of 2, 3, 4, 5 and 6 years after planting.
	Pruning	10 (persons)	350	3, 500	13, 369	Practice in interval of 10 and 15 years after planting.
	Total			109, 150	768, 388	Compound interest in 35 years at interest rate 6%.

		Number	Unit price (yen)	Amount (yen)	Future value (after 35 years) (yen)	Note
Income	Bamboo culms	600(*soku*) 21, 000kg	80	48, 000	676, 377	Delivery at road side (good culms).
	Bamboo culms	400(*soku*) 14, 000kg	60	24, 000		Delivery at road side (slender culms). Culms are yielded only in this generation.
	Subsidy for afforestation			16, 000		
	Yeild in thinning	80(m^3)	3, 400	272, 000	651, 875	Standing trees, 15-25 years after planting.
	Final cutting	360(m^3)	5, 500	1,980,000	1, 980, 000	Standing trees, 35 years after planting.
	Total			2,340,000	3, 308, 252	Compound interest in 35 years at interest rate 6%.
Margin				2,230,850	2, 539, 864	

According to the table, the calculation by compound interest of the future value indicates that it is more profitable to manage a bamboo grove rather than a tree forest. However, there is a difference between a bamboo grove and a *Cryptomeria* forest: the former secures a yearly income even in a small amount, while the latter carries no income until several decades later, though the amount will be large. Therefore, the choice depends on the financial condition of the farmer. Further, in mountainous quarters where bamboo groves are already in use for preventing landslides or soil erosion or where *Cryptomeria* do not grow very well, the attempt to shift bamboos into *Cryptomeria* forests must be done with great care in order to the prevent erosion.

2. Distribution of Bamboo Groves and Production of Sprouts and Culms in Japan

A. Northernmost Limit of Cultivated Bamboo

Bamboos grow well on any kind of ground in districts of mild climate. But they become small in diameter or in height and lose their vital energy in cold districts. On the contrary, the *Sasa* species grow rather well in the districts of low temperature.

The northernmost limit for the growth of bamboo species that produce the culms of large size is as follows.

Ph. nigra var. Henonis	Date, Hokkaido	42°25'	N. L.,	min. temp.	–16. 0°C
Ph. edulis	Hakodate, 〃	41°45'	〃 ,	〃	–18. 0°C
Ph. reticulata	Fukaura, Aomori Pref.	40°40'	〃 ,	〃	–10. 0°C
Semiarundinaria Kagamiana	Aomori Pref.	〃			

Generally speaking, the above data shows also that the latitudinal limit for economical management is the southern part of Aomori Prefecture.

B. Distribution from the Standpoint of Location

Critical studies on the sites (as regards topography, for instance) where

Photo. 41. A scene of bamboo grove cultivated at hill side in Mukomachi, Kyoto (*Ph. reticulata* and *Ph. edulis*)

bamboo groves are needed for their good management. They are commonly located somewhere at the foot of a mountain, on the riverside, in agronomic areas or on farmers gardens, but mostly in the mountainous areas and on the riverside. Those that stand on the upper half of a mountain are

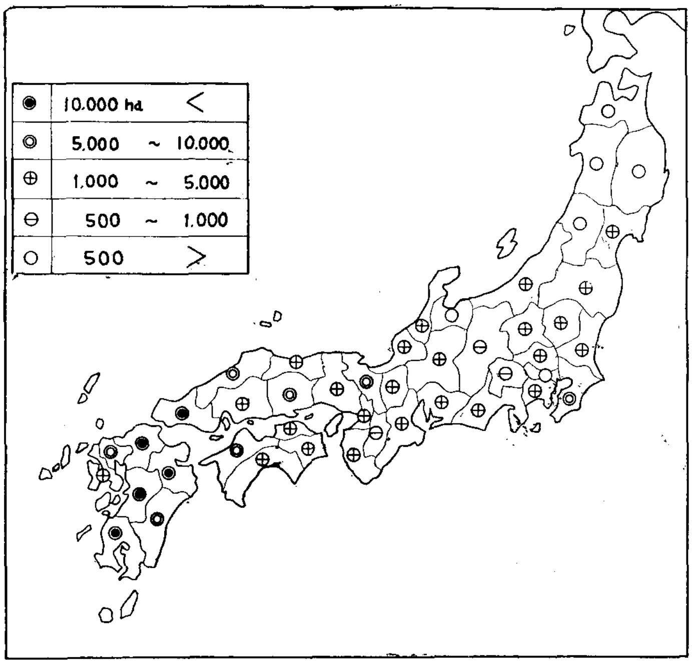


Fig. 30. Prefectural distribution of the area of bamboo groves in Japan

mostly of natural development, and have distributed through a long period of time. Most of the natural bamboo groves mixed with trees are found in mountainous districts. The intensively cultivated bamboo groves are rarely mixed with trees. Bamboos, the sprouts of which are harvested for using as food, is mainly of *Ph. edulis* and is being cultivated at the foot of mountains or hills.

C. Total Surface Area of Bamboo Groves in Japan

The total surface area of bamboo groves in Japan is 168,406 ha. The owners of the bamboo groves are almost private. The *Ph. reticulata* groves (110,000 ha: 70%) occupy the largest area in total, followed by *Ph. edulis* groves (33,000 ha: 20%). The district with the widest area of bamboo cultivation is Kyushu (71,734 ha.). The distribution in each district is as shown in Table 47.

Table 47. Area of the bamboo groves in Japan

By the ministry of agriculture and forest (1956)

Species / District	*Phyllostachys reticulata* (ha)	*Phyllostachys edulis* (ha)	*Phyllostachys nigra v. Henonis* (ha)	*Phyllostachys nigra* (ha)	*Pleioblastus Simoni* (ha)	Total (ha)
Tôhoku	5,033	505			370	5,908
Kantô	10,737	3,590		36	1,545	15,908
Chûbu	10,960	4,082	629	1	954	16,626
Kinki	9,864	4,247	969	163	379	15,622
Chûgoku	21,281	3,959	572	240	1,987	28,039
Shikoku	8,007	4,173	885	353	1,151	14,569
Kyûshû	48,518	13,336	1,892		7,988	71,734
Total	114,400	33,892	4,947	793	14,374	168,406
%	67.9	20.1	3.0	0.5	8.5	100.0

D. Production of Culms and Sprouts for Food

In Japan, groves of *Ph. edulis* used primarily as a source of edible sprouts are cultivated fairly intensively, and the sprouts are an agricultural rather than a forest product. With a few exceptions, groves of this and *Ph. reticulata* etc. managed primarily for production of culms receive little care and for all practical purposes their products are a forest resource.

The bamboo grove area per owner is generally small. Therefore, the management of the bamboo grove for production of culms is generally a side-line.

The annual production of sprouts for food is about 80,000 tons according to statistics.

The statistics of annual culms production show that the total production is 11,387,078 *soku* (300,000 tons) per year, in which those of *Ph. reticulata* and *Ph. edulis* are 6,950,000 and 2,550,000 *soku* per year respectively. The quotient of the total production divided by the total surface area of bamboo groves is only about 70 *soku* per ha. But this seems to be underestimated. Actually more should be produced.

The actual state is, however, that it is not a few bamboo groves which are improperly treated and carelessly left.

More than twice as much as the present production, namely, more than 700,000 tons can be expected. The statistics of the amount of yearly culm production announced by the Ministry of Agriculture and Forestry are as shown in Table 48.

Table 48. Annual production of bamboo culms in Japan

By the ministry of agriculture and forestry (1956)

District \ Species	*Ph. reticulata*	*Ph. edulis*	*Ph. Simoni*	*Ph. nigra*	Rest	Total
Hokkaidô and Tôhoku	190, 513	30, 021	100, 900		202, 241	523, 675
Kantô	1, 190, 850	441, 520	348, 530	5, 320	25, 480	2, 011, 700
Chûbu	897, 844	310, 648	264, 525	3, 250	109, 716	1, 585, 983
Kinki	524, 280	304, 782	44, 940	41, 140	43, 195	958, 597
Chûgoku	1, 301, 650	274, 594	60, 210	20	100, 674	1, 737, 148
Shikoku	530, 125	391, 720	28, 720	11, 620	58, 840	1, 021, 005
Khûshû	2, 317, 300	852, 490	240, 200	3, 280	185, 700	3, 598, 970
Total	6, 952, 542	2, 555, 775	1, 008, 025	64, 890	725, 846	11, 387, 078
%	61. 0	22. 4	9. 6	0. 6	6. 4	100. 0

Unit : *soku*

Phot. 42. A corner of a good grove of *Phyllostachys edulis* in Mukomachi, Kyoto. (maximum diameter 17cm at eye height) annual yield: 700 *soku*(actual volume 18 m^3) per 1 ha.

Phot. 43. A good grove of *Phyllostachys reticulata* in Nagaoka-cho, Kyoto. (maximum. diam. 12cm at eye height) annnal yield: 500 *soku*(actual volume 15m^3) per l ha.

3. Bamboo Cultivation

In order to supply a great amount of culms for pulp industry and other uses, bamboos of good quality must be produced successively every year in quantity.

Although bamboo groves are widely distributed, any over cutting will result in a shortage and the deterioration of quality of raw material. Especially, in the back lands, where more expenses are needed for cutting and transportation. Therefore, the cultivation of bamboo should be studied.

A. Suitable Land

A-1. Climate and Weather

In managing a bamboo grove, knowledge on the conditions of a proper site is necessary not only for the time of planting but also for improving it.

Influential climatic factors are temperature, snow and wind. The minimum temperature should be considered. From the bamboos of the *phyllostachys* species no excellent growth can be expected if the temperature drops below −15°C. For the areas of cold winter, hardy species such as *Ph. edulis* or *Ph. nigra var. Henonis* are commonly prefered. The snow injuries occur by the snow falls in early spring. During this season, snow tends to be greater in specific gravity, and it causes injuries by piling up on bamboos. There is no such problem in the districts of the southern regions. Against the snow injury, either *Ph. edulis*, a snow-proof species, is selected, or some trees are planted in the bamboo grove.

Table 49. Average value of annual climate condition observated during the thirty years (1925–1955)

At the Forest Station of Kyoto University

Month	1	2	3	4	5	6	7	8	9	10	11	12
Average temperature (degree°c)	4.0	4.7	8.6	14.7	20.2	23.6	27.8	29.1	25.0	18.4	12.7	6.9
Max. temp.	7.8	8.5	12.3	18.8	23.7	26.7	30.7	31.9	27.8	21.8	16.2	10.8
Min. temp.	−1.4	−1.0	1.4	6.3	11.5	16.5	21.6	22.3	18.2	11.1	5.3	0.9
Average relative humidity (%)	69.9	66.5	63.3	60.5	62.5	67.5	71,7	67.6	69.8	69.5	70.5	71.3
Average precipitation (mm)	55.1	66.6	105.7	127.9	149.6	226.0	213.5	145.5	185.9	114.6	85.4	60.8

Total Precipitation (annual); 1,536.6mm

Breakages are caused by strong winds or typhoons. The breakage decreases a number of new culms that would be develop the next spring. It is desirable to form windbreaks in a belt form.

For the sympodial type species, above all clump forming species, suitable lands are hard to be found in cold regions as they grow mainly in the tropical regions. *Leleba* species are cultivated in gardens, though they can grow around Kyoto (min. temp. -8°C).

The annual observated results in Kyoto district is shown in Table 49.

A-2. Soil, aspects and gradient

a. Soil condition

Fertile soil, well drained and mixed with gravel, is suitable for the *Phyllostachys* species. But *Ph. edulis* grow even though the soil humidity is somewhat higher, and in the case of cultivation for edible sprouts, it rather prefers soil mixed with clay to the somewhat gravel mixed. *Ph. reticulata* and *Ph. nigra* can grow in soil which is more or less dry.

The following is the result of analyzing on the soil of good and poor bamboo groves (Table 50).

Physical properties; Volume weight is greater in the soil of poor grove; porosity is greater in that of good grove.

Table 50. Physical and chemical properties of the soil of a bamboo grove (average value)

(1) physical properties

Species (grove)	Site grade	Depth of soil (cm)	Moisture (%)	Water-holding capacity Weight (%)	Water-holding capacity Volume (%)	Specific gravity	Volume weight (%)	Porosity (%)	Minimum air capacity (%)
Phyllostachys reticulata	good	0–4	21.9	57.5	49.6	2.59	86.3	66.7	17.2
		16–17	25.0	52.0	50.7	2.63	97.6	62.9	12.2
		30–34	35.0	50.7	51.4	2.64	101.5	61.6	10.2
	poor	0–4	20.8	34.3	40.2	2.58	117.3	54.6	14.2
		15–19	16.8	30.8	39.9	2.63	123.7	53.0	13.1
		30–34	15.5	28.9	38.8	2.61	134.3	48.6	9.8
Phyllostachys edulis	good	0–4	38.8	48.1	47.2	2.32	98.3	57.7	10.5
		15–19	24.5	37.8	44.3	2.41	117.2	51.4	7.1
		30–34	21.4	35.2	42.9	2.46	122.0	50.5	7.6
		45–49	17.7	30.8	39.6	2.44	128.6	48.1	8.5
	poor	0–4	22.2	43.3	44.7	2.45	103.4	57.8	13.1
		15–19	25.0	31.0	39.9	2.44	129.0	47.2	7.3
		30–34	19.8	36.2	45.2	2.50	125.0	50.0	4.8
		45–49	17.0	30.3	39.0	2.50	127.8	41.5	2.5

Locality: Otokuni, Kyoto 1954∼'55

(2) Mechanical composition of soil

Species (grove)	Site grade	Depth of soil (cm)	Per 100g air dry fine soil: Gravel (%)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)
Phyllostachys reticulata	good	0–10	10.3	32.9	15.6	17.5	33.9
		20–30	13.8	21.4	23.9	18.4	36.1
	poor	0–10	5.6	58.4	6.0	12.8	22.7
		20–30	7.3	48.7	15.8	9.3	26.2
Phyllostachys edulis	good	0–10	9.5	33.6	18.7	12.6	34.9
		20–40	17.4	55.5	9.8	7.9	26.8
	poor	0–30	30.2	59.3	3.8	6.6	30.2
		30–50	36.4	60.9	6.4	8.2	24.5

(3) Chemical properties

Species (grove)	Site grade	Depth of soil (cm)	Humus (%)	Total-N (%)	C/N	Hot HCI soluble: P_2O_5 (%)	K_2O (%)	CaO (%)	SiO_2 (%)
Ph. reticulata	Good	0–10	5.72	0.26	12.8	0.14	0.32	0.40	0.16
		20–30	3.61	0.17	12.3	0.15	0.40	0.42	0.15
	Poor	0–10	4.59	0.16	16.6	0.10	0.19	0.22	0.09
		20–30	1.07	0.07	8.8	0.09	0.12	0.12	0.06
Ph. edulis	Good	0–10	6.60	0.24	16.0	0.16	—	0.28	0.22
		20–40	4.13	0.21	11.4	0.13	—	0.20	0.18
	Poor	0–10	5.36	0.17	18.3	0.19	—	0.12	0.11
		30–50	2.98	0.15	11.2	0.16	—	0.08	0.12

(4) Content of available elements in the soil (mg per 100g of air dry fine soil)

Species (grove)	Site grade	Depth of soil (cm)	NH_4-N	1/5N-HCI soluble: P_2O_5	K_2O	CaO	Exchange acidity (Y_1)
Ph. reticulata	good	0–10	4.3	27	30	77	16.0
		20–30	2.4	19	39	93	22.2
	poor	0–10	3.3	23	26	38	14.0
		20–30	2.1	13	24	26	9.9

Sampling place; Nagaoka, Kyoto

(5) Analytical results of bamboo grove soil in India

(5)-a Physical properties of soil

Locality	Soil depth (cm)	Volume weight	Porosity (%)	Maximum water-holding capacity (volume) (%)	Minimum air capacity (%)	Moisture (%)	Bamboo species
Bhavanisagar (Madras state)	0–10	98.45	61.38	44.05	17.33	9.55	*Bambusa arundinacea*
	30–50	105.30	60.50	35.20	25.30	11.20	
	50–70	110.24	58.98	49.20	9.72	14.26	
Cachar (Assam state)	0–20	111.83	57.41	47.17	10.24	26.17	*Melocanna bambusoides*
	40–50	122.81	53.67	42.19	11.48	22.19	
	80–90	116.53	56.42	45.47	10.95	22.47	

(5)-b. **Chemical properties of soil** (% on air dry fine soil)

March, 1959

Locality	Soil depth (cm)	PH (1:1H_2O)	Total-C (%)	Total-N (%)	C/N	1/5N-Hcl soluble P_2O_5 (%)	1/5N-Hcl soluble K_2O (%)	Bamboo species
Bhavanisagar (Madras state)	0-10	5.9	2.15	0.22	9.77	0.010	0.013	*Bambusa arundinacea*
	30-50	5.9	0.96	0.10	9.60	0.006	0.006	
	50-70	5.9	0.74	0.07	10.57	0.008	0.005	
Cachar (Assam state)	0-20	5.3	1.03	0.14	7.36	0.005	0.015	*Melocanna bambusoides*
	40-50	5.3	0.86	0.13	6.62	0.005	0.008	
	80-90	5.3	0.82	0.12	6.83	0.004	0.008	

Chemical properties; All of N, P_2O_5, K_2O, CaO, and SiO_2 are rich in the soil of good groves. PH is low even in the soil of good groves, and bamboos seem to grow very well even in acidic soil.

The soil properties of bamboo groves in tropical regions are different from that of the groves in temperate region. Natural bamboo groves in tropical region are found rarely on laterites and lateritic soil and red soil, widely on black soil and alluvial soil. The analytical results of the soil in India by author et al are shown in the above table. According to this table, amount of various nutrient elements is generally low, above all, humus, avairable phosphorous and potassium are remarkably poor, and C-N ratio is low, but PH is not so much low.

Therefore, on the management of the bamboo groves, the suppling of humus etc. should be done.

Dendrocalamus strictus grows in abundance in India in dry earth at a mountain-side, while *Bambusa arundinacea* thrives in moist ground. But the drainage should be considered because its growth is hindered by stagnating water. In the districts where dry seasons last long, production can be increased by developing irrigation.

b. Soil aspects and gradient

Although bamboos grow well on steep slopes, they loathe a land with too strong sun rays. Generally speaking, the sites facing the north are preferable in regions of mild or warm weather, and those facing the south in cold regions. The sites facing the west receive strong afternoon sun-rays should be rather avoided.

A-3. Vegetation

Various kinds of grasses and shrubs which are called as ground vegetation grow in the bamboo groves. The ground vegetation plays an important role in practical silviculture. Namely, the species of them which have high frequency and cover degree in the bamboo grove indicate the property of the soil and the condition of micro-clima etc. For instance, the species of plants growing dominantly in each bamboo grove in Japan are shown as follows;

1; In the good grove;

Oxalis Acetosella Linn. var. *japonica* Makino; MIYAMAKATABAMI
Boenninghausenia japonica Jacks; MATSUKAZESO
Pollia japonica Thunb; YABUMYOGA
Thalictrum aquilegifolium Linn; KARAMATSUSO
Disporum sessile Don; HOCHAKUSO
Ophiopogon japonicus Ker-Gawler; JANOHIGE

2; In the middle grove;

Lespedeza bicolor Turcz. form. *microphylla* Miq; YAMAHAGI
Liriope platyphylla wang et Tang; YABURAN
Oplismenus undulatifolius Roem. et Schultes var. *japonicus* Koidz; CHIZIMIZASA
Iris japonica Thunb; SHAGA
Cyclosorus acuminatus Nakai; HOSHIDA
Rubus Buergeri Miq; FUYUICHIGO
Polygonatum odoratum Druce var. *pluriflorum* Ohwi; AMADOKORO

3; In the poor grove;

Rubus microphyllus Linn. fil; NIGAICHIGO
Dryopteris erythrosora O. Kuntze; BENISHIDA
Ainsliaea apiculata Sch. Bip.; KIKKOHAGUMA
Spicantopsis niponica Nakai var. *japonica* Nakai; SHISHIGASHIRA
Carex Morrowii Boott.; KANSUGE
Lycopodium serratum Thunb. var. *japonicum* Makino; TOGESHIBA
Polystichum japomicum Diels; INODE
Rhododendron Kaempferi Planch.; YAMATSUTSUZI
Rhododendron reticulatum D. Don; KOBANOMITSUBATSUTSUZI
Vaccinium Smallii A. Gray var. *glabrum* Koidz.; SUNOKI
Pieris japonica D. Don; ASEBI

These indicator plants serve much as refernce to selecting suitable land for the bamboo grove. In case of afforestation, we should be chose an area of the ground vegetation which indicate good site quality.

The ground vegetation which indicates good site quality or good growth of bamboo consists almost of shade plants, while that which indicate poor condition are almost of sunny plants. The root system of the latter plants are widely spread and they hinder the development of the roots of bamboos. Therefore, the shade plants should be always maintained and tended, but sunny plants must be weeded.

The change in environmental factors becomes also the cause of the change of ground vegetation. If an area is covered closely with bamboos and trees, the ground vegetation tends to change to shade plants. But if an area is bare, the sunny plants grow dominantly and cause deterioration of site quality.

Then, we must pay attention to keep the suitable density of bamboo grove and overhead cover. This subject is explained in the section of "Harvesting" of Part Ⅱ.

B. Method of Propagation (planting method)

B-1. Ways of Propagation

Bamboos may be propagated in the following ways;

(1) By culm with roots and rhizome

(2) By the stock with roots and rhizome

(3) By rhizome with roots

(4) By offset planting

(5) By the cutting of culm

(6) By seed or bulbil

For bamboos such as the *phyllostachys* species which propagate by buds of rhizomes, the methods (1), (2) or (3) are mainly used; for the clump forming species of sympodial type, the methods (4)~(6) are usually used.

(1). By culm with roots and rhizome

The culms for this method are used the new young ones sprouted in the same year or the previous year. Although the large-size culms are preferable and also the small-size ones can be used. Leaving the branches on several nodes, the culm with branches of upper part is removed (Fig.31-a). The rhizome of the culm should be yellowish, young, vigorous, and bearing good buds. Old rhizomes should not be used, for they are lacking the buds that develop into culms (photo-44). The length of rhizome is 40~60 cm in length with about ten nodes and buds. Fibrous roots on both culm and rhizome must be leave. The rhizome should be cut carefully with a saw. Cutting with a hatchet will cause damages to the buds due to the strong shock.

Photo. 44. The mother bamboo has not developed new bamboo in 7 years after transplanted, because its rhizome was too old over 7 years.

Photo, was taken at kamigamo-Kyoto in 1959

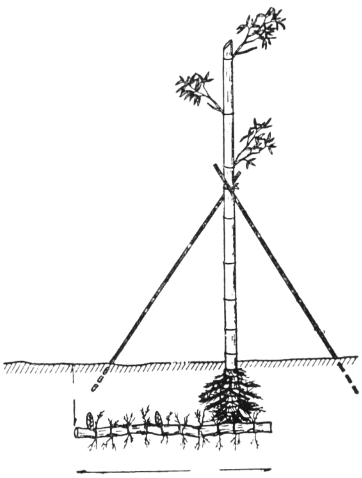


Fig. 31. (a) Culm with rhizome (soil-depth; 30 cm, rhizome-length; 60 cm)

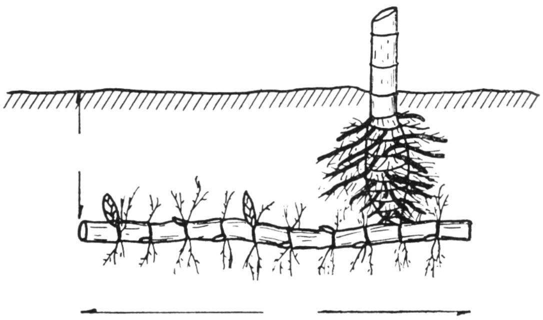


Fig. 31. (b) Stock with rhizome (soil-depth; 30 cm rhizome-length; 60 cm)

(2). By the stock with roots and rhizome

In this case the culm is branchless and its length is about 30 cm. The procedure is the same as shown in above method (Fig. 31–b).

(3). By rhizome with roots

Rhizomes without culm are cut 50~60 cm long with about 10~15 nodes and their roots. The 2~3 year old rhizomes with roots are most satisfactory, but over 5 year old rhizomes are entirely unsuitable.

This method is recommended for transporting to distant places. In this case, they are wrapped with sphagnum moss and covered with vinyl sheets after the soil is washed away. Usually, they are first laid in the nursery bed 20 cm deep and covered with soil (Fig. 31-c). They are transplanted next spring, as new culms begin to grow. In regard to selecting rhizomes, described in above method (1).

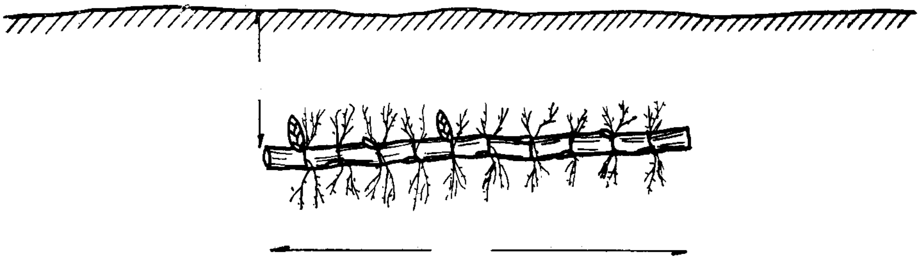


Fig. 31. (c) Cutting of rhizome (soil-depth; 20 cm, rhizome-length; 50 cm)

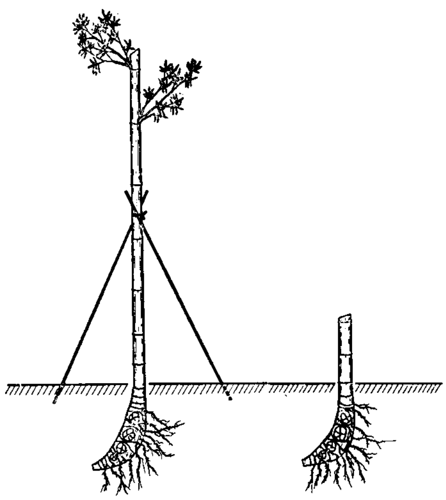


Fig. 31. (d) Offset planting

(4). By offset planting

This is the good method of vegetative propagation of clump-forming bamboo species in which success has been achieved. One-year-old culms which are ready to sprout within the year are cut off with short rhizomes. The culm should be about 30~50 cm in length (Fig. 31-d).

The over two year old culms may be incapable of developing new culms. P. N. Deogun described on the offset planting of *Dendrocalamus strictus* in India, as follows; "The success of this method depends in part on the vitality of the rhizome stock used and the time of the year when it is planted. If the rhizomes are taken from young healthy stock and planted immediately at the break of rain success can be expected. But if the rhizomes are taken from old stock and planted much before the rains, complete failure may result. The weather of the year must also be an important factor."

(5). By cutting of culm

The rooting of the cutting of the monopodial type species (single culm forming species) can be rarely expected in Japan. The author and E. Hashimoto have tested the cutting of *Ph. reticulata* at Kamigamo, Kyoto city on April 7, 1952. Namely, when the number of 50 culm-cuttings 1 m long were stuck in the soil, only one of these had rooted. In this case a new culm developed from a node-bud near the base of the cutting and the new rhizome developed from a node near the base of the new culm.

The cutting of culm of clump forming species is rooted easily; namely, the cutting of branchless culms of 1 or 2 years old and about 1 m long should be stuck or laid down in the soil in the early summer (Fig. 31-e,f).

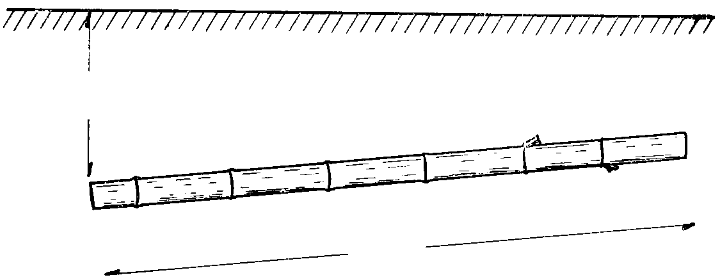


Fig. 31. (e) laying planting (soil-depth; about 30 cm, culm-length; about 100 cm)

(6). By seeds or bulbils (large seeds)

The *Sasa* species or the clump forming species of sympodial type usually develop seeds well. The *Melocanna* propagates by its bulbil, fruit-like seed (Fig. 25).

The seeds are sown in the nursery or in a mountain area. The bamboos produce new culms after sowing every year. But the size of the newly grown culms are slender for several years, so that the normal culms can not be harvested in over 10 years after sowing seeds. Therefore, other methods usually applied for reproduction of bamboo grove.

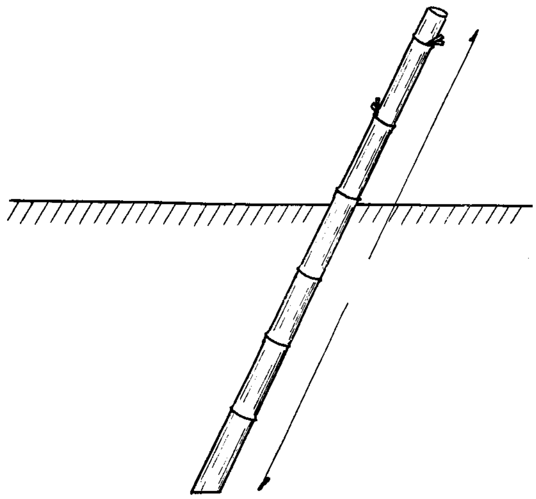


Fig. 31. (f) Cutting of culm (culm-length; 100 cm)

B-2. Season of planting

The optimum months for planting are February (*Ph. edulis*) and March (*Ph. reticulata*) in the cold districts, while November-December in those of warm climate. When the buds on rhizomes slightly show a sign of swelling, it is the best time for the selection of good shoots. Caution must be taken in transportation of such rhizomes for prevention of injury of the buds. The suitable irrigation is recommened when bamboos are uplanted i mountain area.

The new shoot that have sprouted in the same year may be planted very carefully with rhizomes during the rainy season in and after June.

In the tropical regions, the rainy season from spring to summer is the optimum season for planting, because the dry season is usually in winter.

B-3. Number under planting

The greater the number that is planted per ha the earlier the bamboo groves are completly established, and harvest can be started. When the soil is fertile or the species is a type of large-size culms, plantation is done less densely than the case of poor soil or of the species developing culms of small size. Generally speaking, the number to be planted is 300~500 per ha (space 4~6 m) for *Ph. reticulata* or *Ph. edulis*.

B-4. Method of planting

Instructions for planting are as follows;

(1) The junctions of culms and rhizomes should not be injured.

(2) The bamboos should be planted, after being dug up as soon as possible. For the transportation to a distant place, rhizomes are cut with roots but without the culms; and then wrapped with sphagnum moss after the soil has been rinsed away.

(3) After planting, they are irrigated and fertilized. The direct contact of fertilizers with the bamboo roots should be avoided. The fertilizer is applied in the following proportion per ha, N, 100 (good soil) ~ 200 kg (poor soil); P_2O_5, 50~100 kg; K_2O, 50~100 kg. If solid manure is to be used, 700~1,000 kg per ha is applied.

(4) On a sloped land, rhizomes are planted in such a way that the buds come out on the upper side of the slope.

(5) Windbreak trees are planted either on the periphery of or on vacant lots within the area for planting. Some trees for shades are necessary in the tropical regions. The plants of *Leguminosae* grow rapidly and will be useful for this purpose.

C. Weeding and Fertilization

C-1. Weeding

The bamboos produce new culms asexually after planting every year. The size of new culms is slender for 2~3 years, large-size culms newly grown gradually, but the culms can normally be harvested in 6 ~10 years. In order to raise large yields, 4 ~ 5 year-old culms should be cut in addition to annual fertilizing. Sunny herbs hinder the growth of bamboos, therefore they must be weeded.

Later, when bamboos thrive and shade the ground, the shade grasses begin to grow thickly. These grasses do not hinder the growth of bamboos and the weeding is not necessary. This leads to a conclusion that the density of bamboo grove must be controlled to prevent the sunrays strongly coming onto the ground.

C-2. Fertilizer application

The bamboo consumes a lot of inorganic nutrients in order to grow and propagate. These mineral salts are supplied naturally through the soil or rain. Bamboo grove where no fertilizing, the culms can be harvested a limitted amount corresponding the natural supplies of nutrients. Once the amount of harvest exceeds the level, however, fertilization will become necessary to make up for the deficit caused by the increment of harvest. To increase the yield per unit area not only lowers the cost of transportation to factories, but also raises the culm production. In operating paper mills, increasing yields by fertilization plays an important role. Although yield depends on such a factor as the condition of the soil, yearly yield is 9 m^3 or 10 tons (fresh weight) per ha in the grove of *Ph. reticulata*, and 12 m^3 or 13 tons (fresh weight) per ha in that of *Ph. edulis* in the soil of mean quality, if thinning is done properly.

In the case of the clump-forming species in the tropical regions, it is 4 ~ 5 tons per ha every year at the most due to improper thinning in spite of the fact that high temperature is favourable to their growth.

The author et al conducted some experiments on the chemical analysis of culms and rhizomes with regard to the mineral nutrients and the quantities that the bamboo requires and on the time and place of fertilizing, further fertilizing tests at the producing center. The following shows an outline of the results.

a. Three elements

The fertilizing tests were conducted at the groves of *Ph. reticulata* and *Pleioblastus pubescens* (pot test).[1][2] Nitrogen is the element of most requi red by bamboos, followed by potassium and phosphate. It was found that these three elements are most effective when used together. The total fresh weight of the culms, branches and leaves of *Pleioblastus pubescens* decreased to 0.8 times at non-N plots, while they increased to 1.2 times at non-P plots, to 1.5 times at non-K plots, and to 2.9 times at 3-element plot for the non-fertilized plots. The total fresh weight of rhizomes at the three-element plots also increased to 2.5 times even in non-fertilized plots. It was further detected by chemical analysis of culms and rhizomes that the amount of K_2O absorption is higher as compared with those of N, and P_2O_5 (Table 51—(1), Photo. 45—(1)~(5)).

The total product of new culms of *Ph. reticulata* grove in one year suggests the necessity of applying the three elements mixture (Table 51~2).

The experiment at the *Ph. reticulata* groves shows the results; 1 represents the product of non-fertilized plots (900 kg products per 0,1 ha), then 1.3, 1.4 and 1.6 (about 1,400 kg per 0.1 ha) times at non-K, plots, non-P, plots, and 3-element plots respectively.

Table 51. Result of three-elements test

(1) *Pleioblastus pubescens*

Transplanted; 1954
Fertilized; August 1955 and August 1956 investigated; August 1957
Per 1 plot (diameter 1 m = 0.7825 m^2.)

Growth in a year after fertilizing / Plot (treatment)	Culms						Rhizomes				
	Number of culms	Average diameter at base (mm)	Whole length (average) (cm)	Fresh weight of leaves (g)	Total fresh weight (culms, branches, leaves) (g)	Index number by total weight	Total elongation (cm)	Diameter (average) (mm)	Total fresh weight (g)	Index number by total weight	Number of branches
Complete plot (three elements)	46	4.6	72	166	526	100	1877	5.9	745	100	40
Non-nitrogen plot (nitrogen lacking)	15	4.7	57	34	147	28	677	5.8	325	44	8
Non-phosphorus plot (phosphorus lacking)	16	4.7	74	49	215	41	810	5.7	325	44	11
Non-potash plot (potash lacking)	21	4.4	78	64	281	53	1005	5.3	405	54	20
Non-fertilizing	17	3.8	63	46	182	35	774	5.0	288	39	8

Remarks; Applided amaunts of fertilizers (per 1 plot)
124g. Ammonium sulphate (N; 26g)
86g. Superphosphate of lime (P_2O_5; 13.8g)
49g. Potassium sulphate (K_2O; 23.5g)
Locality; Experimental Station of Kyoto Univ.

Table 51. Result of three-elements test

(2) *Phyllostachys reticulata* grove

Fertilized; August 1956. area of 1 plot; 100 m² (10×10m)

New culms produced in 1-2 years after fertilizing / Kinds of plot by applied fertilizer (treatment)	Number				Fresh weight (kg)				Diameter at eye height (average)			
	1st year (1957)	Index number	2nd year (1958)	Index number	1st year (kg) (1957)	Index number	2nd year (kg) (1958)	Index number	1st year (cm) (1957)	Index number	2nd year (cm) (1958)	Index number
Complete plot (three elements)	36.0	100	33.0	100	162	100	156	100	4.95	100	5.25	100
Non-nitrogen plot (nitrogen lacking)	23.5	65	20.0	61	108	67	93	60	5.20	105	5.15	98
Non-phosphorus plot (phosphorus lacking)	30.5	85	26.0	79	147	91	102	65	5.25	106	4.45	85
Non—potash plot (potash lacking)	28.5	79	30.0	91	135	83	132	85	5.15	104	4.45	85
Non-fertilizing plot	26.0	72	13.0	39	102	63	60	39	4.70	95	5.10	97

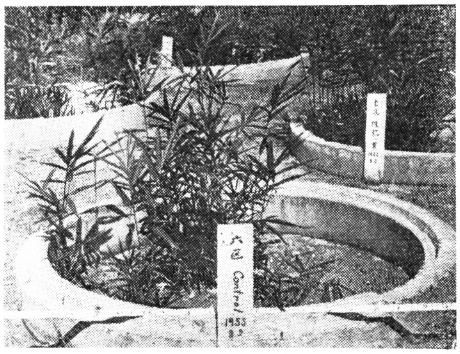
Remarks; Applied amounts of fertilizer per 100m²
7.35kg, Ammonium sulphate (N; 1.5kg)
3.38kg, Superphosphate of lime (P_2O_5; 0.56kg)
1.24kg, Potassium sulphate (k_2O; 0.56kg)
Locality; Mukomachi, Kyoto (1957～'58)

Photo. 45. The fertilizer test

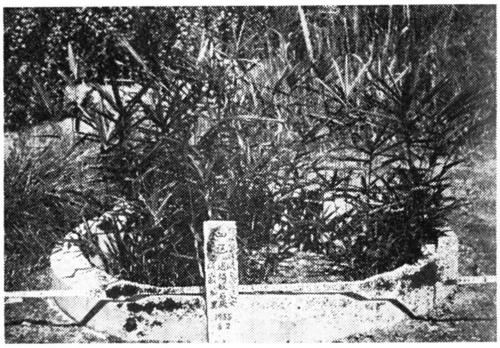
Following five photographs were taken in 1 year after the second fertilizing at the plot of *Pleioblastus pubescens*

(manuring; Aug. 1955 and Aug. 1956)

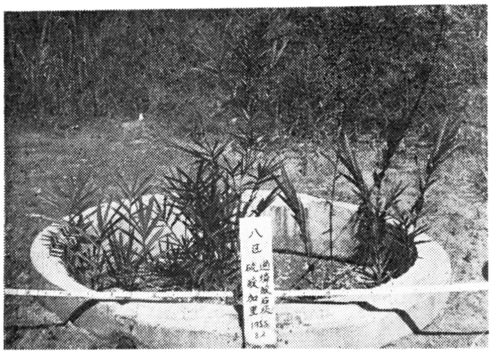
Details are explained in Table 51.



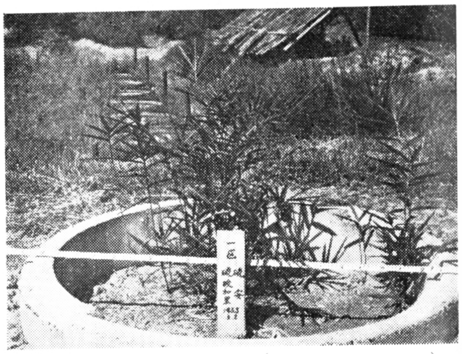
(1) Non fertilizer plot. Photo.: Aug. 1957



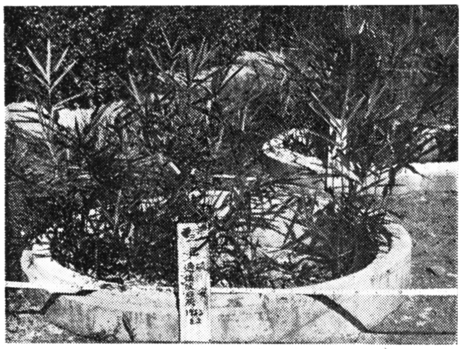
(2) Complete plot (three elements plot)



(3) Non nitrogen plot (nitrogen lacking)



(4) Non phosphorus plot (phosphorus lacking)



(5) Non potash plot (potash lacking)

b. Amounts of the three elements to be applied

The amounts of the three elements required for the increase of production by 10 *soku* (350 kg, fresh weight) per 0.1 ha from the grove of *Ph. reticulata* are determined by the following analysis, as shown in Table 52.

Table 52. Content of four elements in *Ph. reticulata* (average)

Parts	Air dry weight per 10 *Soku* (kg)	Total-N (%)	Total-P_2O_5 (%)	Total-K_2O (%)	Total-SiO_2
Leaves	40	2.3	0.3	0.5	5.0
Culms and branches	340	0.3	0.1	0.4	0.4
Rhizomes	250	0.7	0.2	0.5	0.5

Table 53. Results of fertilizer experiment on optimum quantity of nitrogen in *Phyllostachys edulis* grove

Applied quantity of N (kg)	Standing bamboos before fertilizing			New culms produced in the 1st year after fertilizing			Required quantity of nitrogen for the increment of 10 *sokus* per 0.1 ha. (kg)
	Number	*Soku*	Average diameter at eye height (cm)	Number	*Soku*	Average diameter at eye height (cm)	
N-45	650	444	10.0	180	82	8.4	8.0
N-35	490	404	10.8	120	83	9.5	6.1
N-24	740	326	8.5	180	47	6.7	11.4
N-12	640	196	7.2	170	41	6.4	8.0
N-0 (nitrogen lacking)	520	248	8.8	60	26	8.5	—

Remarks; *Soku* is bundled the marketing unit in Japan.
1 *soku* = 35 kg fresh weight (*Ph. reticulata*)
32 kg 〃 (*Ph. edulis*)
N: Ammonium sulphate
Fertilized: 1955
Locality: Fushimi, Kyoto (1956~'57)

The rate of absorption must be taken into account when fertilizers are applied. If the rate of absorption is assumed to be 30%, 20%, and 50 % for N, P_2O_5 and K_2O respectively by calculation, about 9kg, 5kg, and 6 kg of N. P_2O_5 and K_2O respectively are required for the increase of production by 10 *soku* (350 kg) per 0.1 ha every year.

Table 54. Results of fertilizer experiment on optimum quantity of nitrogen in *Phyllostachys reticulata* grove (volcanic ash soil)

Applied quantity of N	New culms produced in the 1st year after fertilizing			Required quantity of nitrogen for the increment of 10 *soku* per 0.1 ha.	Remark
	Number	*Soku*	Average diameter (cm)	(kg)	
N-0.kg (nitrogen lacking)	458	11.6	1.7		N : Ammonium sulphate
N- 7.5kg	804	21.7	1.9	7.5	
N-22.5kg	1058	31.6	1.6	11.3	

By H. Wakatsuki
Locality: Chiba prefecture
Fertilized: 1955
Investigated: 1957

Some examples of fertilizing tests in the groves of *Ph. edulis* (Kyoto Pref.)[3] and *Ph. reticulata* (Chiba Pref.)[4] reveal that 6 ~10 kg of nitrogen is needed for an increase of annual production by 10 *soku* (350 kg) per 0.1 ha which as calculated above.

The maximum effect by nitrogen on the increase of production extends only to 23 kg and no further increase in production can be expected even by the increment of nitrogen application. If nitrogen is applied more than 35 kg the quality of the culm becomes soft though the yield is raised to a certain extent; to prevent this SiO_2 must be applied together with other fertilizers. Further, the amounts of three elements vary according to soil aspects. In a volcanic ash soil which has a high absorption coefficient of P_2O_5, the actual amount of phosphorous fertilizer to be applied must be more than the required amount by the bamboos (Tables 53, 54).

Although no sufficient fertilizing test has been conducted on clump-forming species, some analytical results obtained from their culms and rhizomes and fertilizing test are shown in Table 22—(3), (4) 56.

The above Table 22 shows that *Melocanna* is particularly richer in SiO_2 as compared with *Phyllostachys*, but for the rest they are not markedly different.

c. Effect of the various kind of nitrogen fertilizers

According to the experiment, the production of new culms in the *Ph. reticulata* grove is remarkably increased after every application of nitrogen fertilizers. The difference of the effects of fertilizer is not founded among the inorganic or organic fertilizer. The kinds of fertilizer used are solid-fertilizer, urea, ammonium chloride, calcium nitrogen, ammonium nitrate, ammonium sulphate, barnyard manure, and night soil.

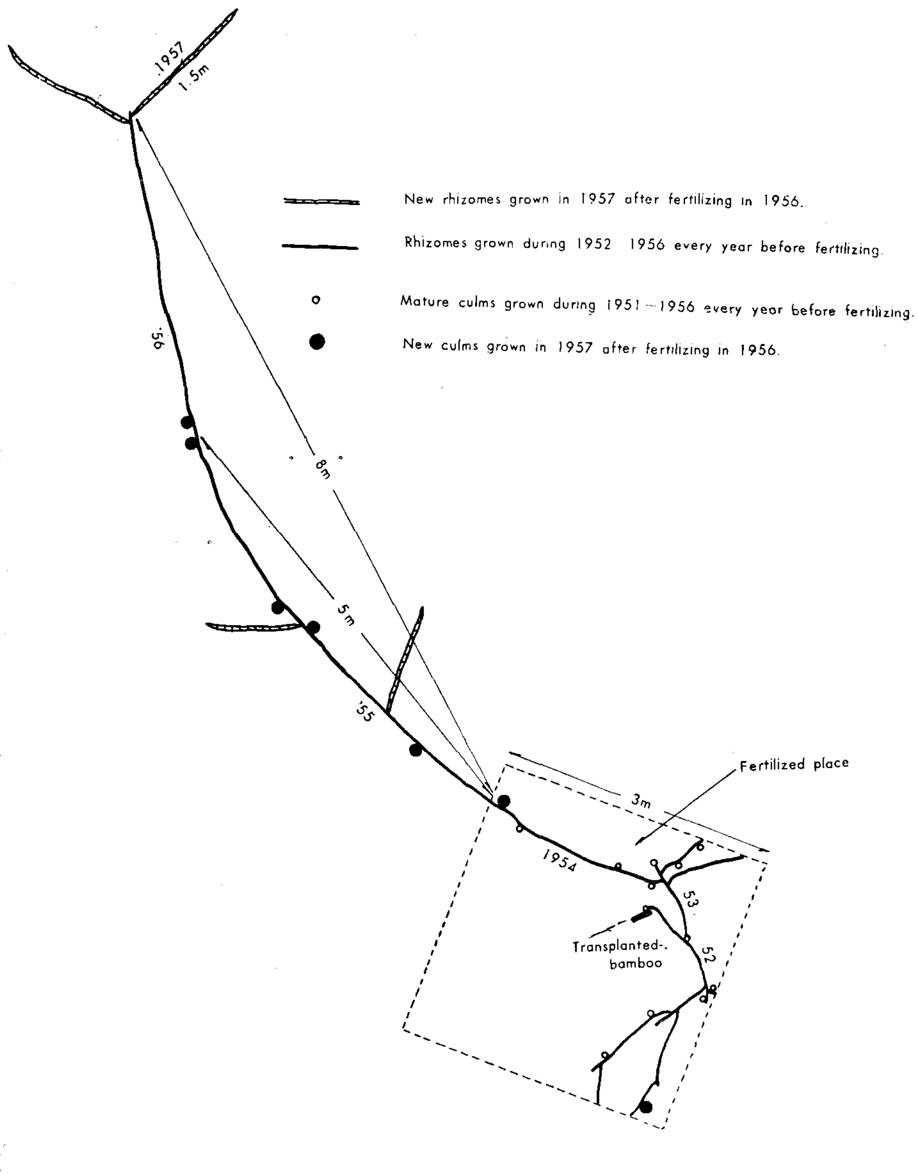
d. Other elements (Silicate)

Silicate (SiO_2) is contained roughly more than 5.0 % in the leaves, about 2.0 % in the branches, about 0.4 % in the culm, and about 0.5 % in the rhizome. SiO_2 is effective in increasing the culm production. Then, details are as shown in Table 55. According to this table, it is noted that a lot of SiO_2 is contained in the out-side portion (exodermis) of a culm.

The leaves must be left in the grove after cutting off the branches at the harvesting. Because silicate is effective in increasing the culm production.

Especially when nitrogen is applied in a great amount, addition of SiO_2 is indispensable. Calcium silicate is commonly applied at about 30 kg per 0.1 ha., Experiments are being carried out on other elements at present.

Fig. 32. An extention of rhizomes and the distance from fertilized place to effecting part in *Phyllostachys reticulata* grove



Locality; Kamigamo, Kyoto (Dec. 1957)

Table 55. SiO_2 quantity contained in several bamoo species. (% on air dry matter)

Parts \ Bamboo species		*Phyllo-stachys edulis*	*Phyllo-stachys reticulata*	*Leleba multiplex*	*Shibataea kumasaca*	*Pleio-blastus pubescens*	*Sasa paniculata*
		%	%	%	%	%	%
Leaves		5.68-6.78	7.40-8.50	8.47-9.57	7.40	15.30	5.70-8.00
Branches		2.20-2.85	2.85-3.50	3.00-4.93	—	—	2.60-3.05
culm	outer portion (exodermis)	4.20-5.10	4.35-4.60	—	—	—	3.60-4.45
	inner portion (wall)	0.10-0.13	0.13-0.18	—	—	—	0.25-0.25
	node	0.31-0.32	0.49-0.59	—	—	—	1.20-1.30
Whole culm (average)		0.29-0.33	0.47-0.60	0.30-0.40	2.05	3.00	1.50-1.70
Rhizome		0.25-0.33	0.45-0.55	0.60-0-77	0.85	1.65	0.80-1.03

Locality: Kyoto (1957-'59)

e. Extent of fertilizer effect

On the species that thrive by extending shoots of rhizomes in the form of networks, the distance from the fertilized place to the effecting part is detected. According to the experiments conducted by the author et al., most of the assimilates produced by these mature bamboos translocate in

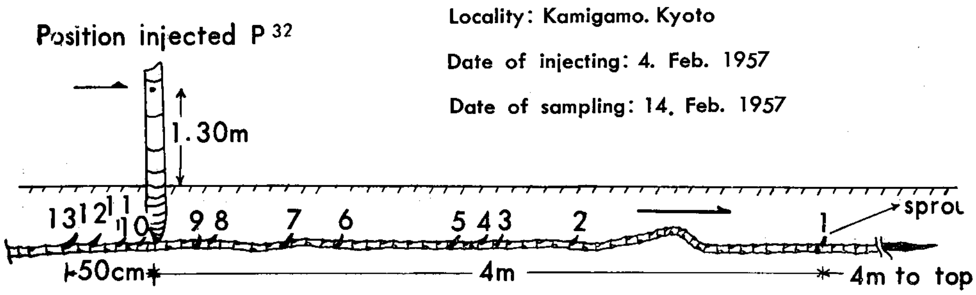
Photo. 46. Injecting radioisotope P^{32} directly into the hollow of the culm.

Photo. 47. P^{32} translocated at sprout through culm is traced by G. M. counter.

the direction of growth of rhizome (Photo. 46, 47 and Fig. 33).[5] When fertilizers are applied near the mature bamboo, the effects on the development of new bamboos is detected to 5~6 m long in front part (growth-direction) of the mature bamboo; most remarkable effect appeared on the portion closest to the mature bamboo fertilized. The effect on the growth of these new rhizomes extends farther, for they start growing from the apical point where their elongation ceased in the previous year. According to a fertilizing test, the effect was detected in the part 9 m distant from the fertilized place (Fig 32).

The above phenomena were also confirmed by the experiments with radio isotope p^{32} [6], gibberellin[7] and by other fertilizing tests[8] (Fig. 33, 34. Photo. 48).

Fig. 33. Absorption and translocation of P^{32} in winter
(*Phyllostachys edulis*)



Remark;

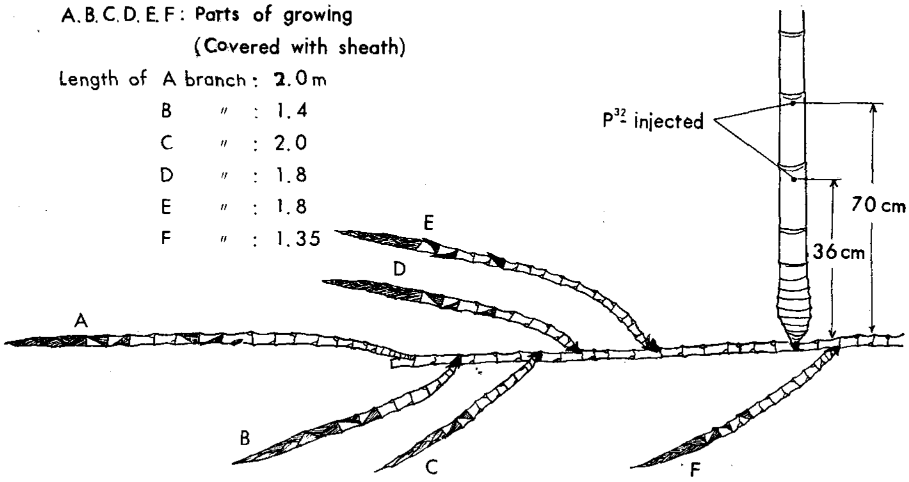
Number of bamboo sprouts	1	2	3	4	5	6	7	8	9	10	11	12	13
Distance to bamboo sprout from mature culm injected P^{32} (m)	4. 22	2. 18	2. 11	1. 85	1. 78	1. 28	0. 59	0. 19	0. 14	-0. 17	-0. 25	-0. 45	-0. 52
Count/minute/1g, dry matter	176	64	137	136	160	106	192	119	176	101	143	63	Natural

Fig. 34. Absorption and translocation of radio isotope P^{32} in
Phyllostachys reticulata
(Kyoto 1956)

Remark;

	Branches of a culm						Rhizome A			Rhrzome B			Culm	
	Lower part		Middle Part		Top part		Top part	Middle part	Basal part	Top part	Middle part	Basal part	20cm on the ground	1. 47m on the ground
	leaves	twigs	leaves	twigs	leaves	twigs								
Ash wt.g	0. 170	0. 048	0. 138	0. 034	0. 156	0. 048	0. 055	0. 124	0. 072	0. 126	0. 093	0. 086	0. 055	0. 042
CPM	54	15	25	N	27	N	13	8	N	11	N	16	13	13
CPM/Ash 1mg	1. 28	1. 28	0. 72		0. 68		0. 96	0. 24		0. 36		0. 76	0. 96	1. 24

N; Natural



f. Place (position) and season of fertilizer application.

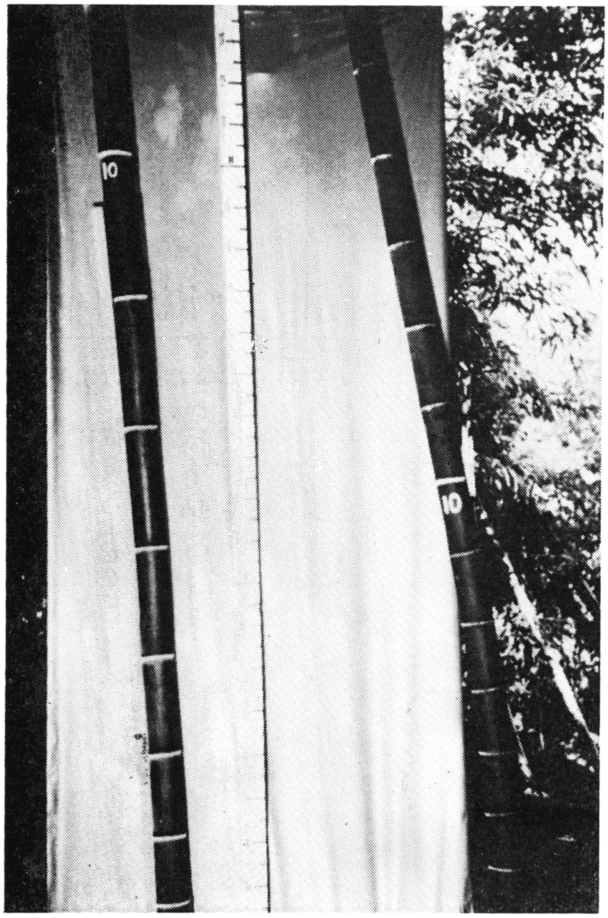
In the species that thrive by extending its rhizomes annually, the rhizomes of 2–5–6 years old are vigorous and these rhizomes produce new culms in a great number. Therefore, fertilizing is more effective if it is spread on the near place of young mature bamboos. Yet it is natural that the fertilizing effect should appear close to the site of application in the case of the clump forming species.

The application may be done any time if the fertilizer of slow effect is used. In the case when a fertilizer of rapid effect is used, the application to be effective should be done about a month in advance of each season of growth, so that the effect occurs at the season of sprouting and rhizome growth. For instance, it is February–March and June–July for *Ph. edulis* grove, March—April and June—July for *Ph. reticulata* grove around kyoto district. The spring appliction has an effect on the development of sprouts of the same year. The rhizomes are grown thick by the summer application. Therefore the general effect on culm growth can be detected after 1～2 years.

For the *Leleba* species of clump forming type, this was confirmed through the experiments conducted by the author at the experimental site of Kyoto University. Namely, in the *Leleba multiplex* on which fertilizing test is being conducted, the effects of application from July to August were remarkable and the new culms grew in the same year and the next year after the application produced an increas of number by several times compared with those at non-ferilized plots (Table 56, photo. 49-(1)(2)(3)).

Photo. 48. A result of gibberellin treatment on *Phyllostachys edulis* at Kyoto

Left: elongated internodes after treatment
Right: control



(Method of treatment)

The Gibberellin solution (40ppm, 100cc) was injected into the hollow of 11 th internode of culm (2 years old culm) in Mar. 28, 1958.

(Result)

The new culm(Left hand)developed out of ground in a week after injecting, and internode length of the new culm was longer than the length of injected 2 year old culm.

The experimental data is as follows;

	Right hand	Left hand
Diameter at eye height (cm) (150cm above ground)	7.0	7.4
Diameter of 10th internode above ground (cm)	7.2	7.4
Length of 10th internode above ground (cm)	16.9	32.4
Height of 10th nodes above ground (cm)	125.0	196.0

Table 56. The effect of seasonal fertilizing on the growth of *Leleba multiplex* grove

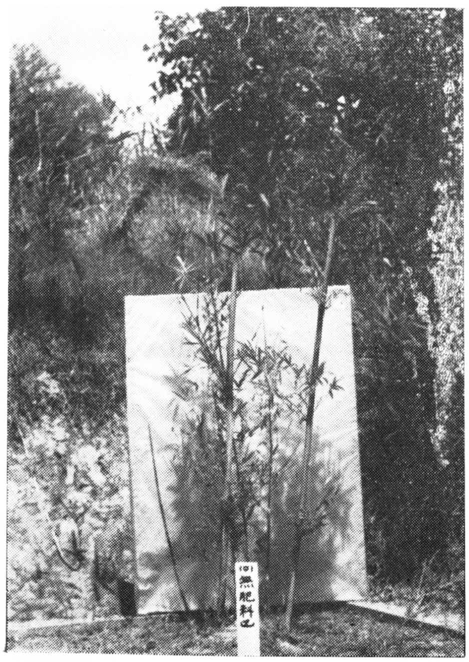
(mean of duplication)
Locality: Kamigamo, Kyoto

Month of treatment \ Number of new culms	Number of new culms grown in 1958	Number of new culms grown in 1959	Total number of new culms
Fertilizing in Feb.	7.5	24.5	32.0
〃 〃 Apr.	6.5	32.5	39.0
〃 〃 June	7.5	33.5	41.0
〃 〃 July	8.0	48.5	56.5
〃 〃 Aug.	9.5	37.5	47.0
〃 〃 Oct.	11.0	29.0	40.0
〃 〃 Dec.	8.5	30.5	39.0
Non-fertilizing	6.5	16.0	22.5

For *Dendrocalamus strictus*, *Bambusa arundinacea* and *Melocanna bambusoides*, fertilizing test should be practiced by the analitical data (Table 22-(3), (4).)

Photo. 49. The effect of seasonal supplies of fertilizers on the growth of *Leleba multiplex*

(Details are shown in Table 56)



(1) Non fertilizer plot.

(2) Ammonium sulphate, superphosphate of lime and potassium sulphate plot fertilized in winter.

Remarks:

The purpose of this experiment is to find the optimum season of fertilizing on growth of *Leleba multiplex*. Experimental method were as follows:

Area of experimental plot 2×2 m and each treatment in duplicate. Three mature culms were planted in each plot in June 1958 and then fertilized.

Fertilizer was supplied as ammonium sulphate 510g, superphosphate of lime 360g and potassium sulphate 180g.

The number of new culms was investigated in October 1959.

(3) Ammonium sulphate, superphosphate of lime and potassium sulphate plot fertilized in summer.

g. Method of fertilizer application

Fertilizers spread and covered with soil. They may be scattered over the ground, but the effects appear slowly in this case, for they do not dissolve without rainfall. Further it was found experimentally that foliage-spray of manure also proves to be effective. A radio isotope was sprayed on the leaves of *Ph. reticulata*[9] in summer and examined after a week. It was moving in active parts such as the apex of a rhizome and in every part of the culm. But the amount of absorption is restricted in this case as the surface of a bamboo leaf is smooth. Therefore, the application must be repeated several times in the case of foliage-sprays.

References ; 1) Transaction, KANSAI Branch, Jap. Forest. Soc. No. 7, 1957, No. 8, 1958.
2) Bulletin of the Kyoto University Forest. No. 28, 1958.
3) Ibid.
4) Report No. 1, On Improving Test of Bamboo Forest. Forestry Section, Chiba Pref., 1957.
5) Transaction, KANSAI Branch, Jap. Forest. Soc. No. 6, 1956.
6) Ibid.
7) Reports. Gibberellin Association. 1958.
8) Bulletin of the Kyoto University Forests. April, 1960.
9) Transaction, KANSAI Branch, Jap. Forest. Soc, Nov., 1959

D. Harvesting

When a bamboo grove is newly afforested, it is only after 8-9 years that a normal yield can be expected annually. The proper treatments, when the grove is completely established, will be given in the following.

D-1. Cutting age.

A proper cutting-age must be studied not only in the aspect of utilizing culms but also in that of culm production. According to the results from an experimental work, if it is too young cutting age the new culms become large in number, but small in size. On the other hand, if it is too old cutting age, the new culms become somewhat large in size, but small in number.

From these facts, the suitable cutting age is about four years for *Ph. reticulata,* about five years for *Ph. edulis,* that produce culms of large size, and about three years for *Ph. nigra* that produce culms of small size. But when many new culms develop due to the application of fertilizers, the age may become about one year shorter. On the other hand, in cold districts the development of new culms in number is restricted and the cutting age will become somewhat longer. Also culms growing on the riverside are rather soft and the cutting age of them may be deterred for the use of manufacture.

In the clump-forming species of sympodial type, bamboos from one to three years old play the most important role, because new culms grow from those buds on the basal part (underground) of one-year-old rhizomes, and two and three-year-old bamboos serve in supplying nutrients needed for the growth of sprouts. Therefore, bamboos of 1～3 years old must always be left in reserve. It is better for the development of new culms to remove the bamboos of over four years old.

Although cutting is to be done based on the age, bamboos of poor quality or those injured by insects or diseases must be removed regardless of age.

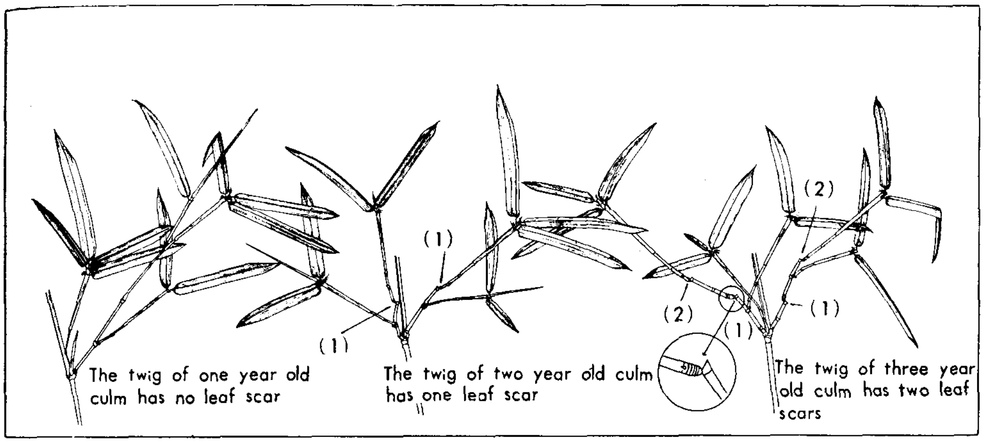
D-2. Determination of the culm age

The size of a culm is no criterion of its age. The one or two year old culms are easily recognizable by colour of culm or that of sheath at the base of a culm (*Ph. reticulata*) and the white waxy powder on the internodes (*Ph. edulis*). Furthermore the age of a bamboo can be determined exactly by counting the leaf scar (base-node) on leaf-sheath in autumn or winter as shown in Fig.35. Because bamboo leaves fall in a year or a year and a half, and develop soon new leaves from the near node of leaf-fall-portion and the relief of new and old leaves on the some of branches take place from spring to summer.

In a practical management, it is desirable that new culms be marked every year on them in the year which they have grown.

On determing the age of *Sasa*. new or one year culms are recognizable by few or no branches on them. Still older culms are distinguished by the number of branches.

Fig. 35. The method of determination of culm age by counting the number of leaf scar



P. N. Deogun has described on the method of counting age of *Dendrocalamus strictus* in India as follows;[1]

"New or one-season old culms produced in the last rains, have fresh looking bracts still adhering to the nodes and a coating of white waxy bloom on the internodes which comes off with lightest touch; they usually have few or no branches,

Two-season old culms may still retain the bracts in certain localities, but if so they are withered and darkish in colour, sometimes erect and sometimes hanging on the nodes. The internodes are greenish in colour with a thin bloom spread fairly uniformly, though thicker near the nodes; it comes off when a finger is lightly rubbed over it, side branches are present on the nodes, having just been formed.

Three-season old culms generally have no bracts, but if any remain they are discoloured and weatherworn and prevented from falling by some obstruction. The bloom is no longer uniform but is variegated by darker blotches and is not readily removed by rubbing,

Four-season old culms are green with little or no bloom. On cool sites there are generally gib dark blotches on the surface of internodes which can be rubbed off easily.

Still older culms show yellow patches in the green. These are a sure sign of full maturity."

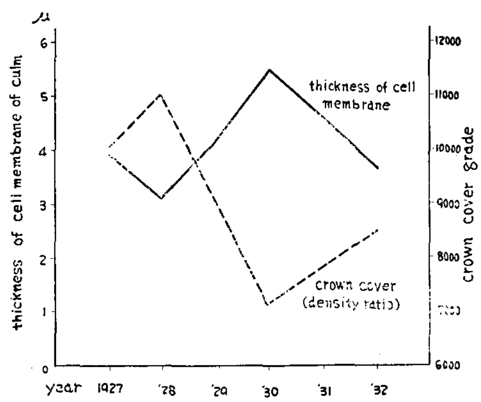
D-3. The number of culms to be retained (Density of bamboo grove)

The important thing in managing a bamboo grove is to leave the bamboos of good quality being properly spaced. In the case of the clump-forming species of sympodial type, the number of bamboos per a clump must be considered.

Generally speaking, the bamboos of smaller-size species are grown more densely, where the quality of the soil becomes poorer. Dr. S. Uno made an experiment on the quality of the bamboos, and reported that the cell-walls of a culm become thicker, where bamboos are grown sparsely[2] (Fig. 36).

Fig. 36. Relation between crown cover of grove (density ratio) and thickness of cell membrane of culms in *Phyllostachys reticulata* grove

by Dr. S. Uno



An investigation on the suitability of density in a bamboo grove was made in a grove of the *Ph. reticulata.* Some plots of the same soil-property (medium) were selected for the plots where 1,200, 900, and 750 mature bamboos per 0.1 ha after thinning are retained. The thinning for harvest is put in to practice every year. The number of every yearly grown new bamboos and the yields were recorded for eight successive years, as shown in Table 57.

Table 57. Effect of density of *Phyllostachys reticulata* grove on newly grown bamboos and yields of culms a year per 0.1 ha.

By Mr. Tarao,
Figures represent average.

	Item	Density of grove			Note
		high	fairly high	medium	
Culms remained after harvesting	Number	1,200	900	750	December-May
	Fresh weight (kg)	6,150	4,680	3,450	
	Age	1-9	1-7	1-5	
New culms per year	Number	165	179	218	May-June
	Fresh weight (kg)	1,125	1,140	1,143	
	Diameter at eye height (cm)	6.7	6.3	5.9	
Injured new culms	Number	71	30	26	during cutting
	Ratio to number of new producing culms (g)	43.0	17.0	12.0	
Culms before harvesting	Number	1,365	1,079	968	July-October
	Fresh weight (kg)	7,275	5,820	4,593	
Annual yield of culms	Number	165	179	218	harvesting in October-November
	Fresh weight (kg)	750	870	990	
	Ratio to number of standing culms before harvesting (%)	12.1	16.5	22.5	
	Ratio to fresh weight of standing culms before harvesting (%)	10.3	14.9	21.6	

Locality: Kizu-cho, Kyoto (1927~'35)

According to this table, the number of newly grown bamboos is largest in section 750, and decreases in the order of the section 900 and the section 1,200. Since the culm size is small in section 750, the volume (in *soku*) is almost the same in any one of the sections. More bamboos were injured in 1,200 section and the yield was greatest in section 750 and in section 900.

Therefore, in a grove of the *Ph. reticulata* that grows these culms of 6~7 cm in average diameter, the proper number of bamboos retained after harvest-cutting is about 800 per 0.1 ha. Next Table 58 will be shown the standard number of standing bamboos per 0.1 ha. by the quality of the soil, which are to be left.

Table 58. Standard number of standing-bamboos retained after harvesting

(Per 0.1 ha.)

Site grade / Species	Good	Medium	Poor
Phyllostachys reticulata grove	700- 800	800-1,000	1,000 over
〃 *edulis* 〃	400- 500	500- 700	700- 900
〃 *nigra var. Henonis* 〃	700- 900	900-1,200	1,200-1,500
〃 *nigra* 〃	1,500-2,000	2,000-3,000	3,000-4,000

Table 59. Distribution of number of bamboos by each diameter grade at eye height

(1) *Phyllostachys reticulata* grove per 0. 1 ha.

D. E. H. (cm) / Site grade	2	3	4	5	6	7	8	9	10	11	12	13	Total number	Average diameter (cm)	*Soku*	Fresh weight (ton)
	number															
Good			10	30	40	80	40	90	210	190	100	20	810	9. 1	516	18. 1
Poor	250	560	480	150	10								1, 450	3. 3	93	3. 3

(2) *Phyllostachys edulis* grove per 0. 1 ha.

D. E. H. (cm) / Site grade	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total number	Average diameter (cm)	*Soku*	Fresh weight (ton)
	number																	
Good						6	10	44	130	178	156	118	18	2	662	12. 9	878	28. 1
Poor	90	180	260	270	180	50									1, 030	6. 2	239	7. 6

Remark: D. E. H. -diameter at eye height
Locality: Kyoto (1954)

The above Table 59 shows the number of culms by diameters grade at eye height in grove.

Table 60. Investigated data on culms and clumps of natural bamboo groves in India

Investgated; from Feb. to Mar., 1959

Species (grove)	Per ha. Number of clumps			Per ha. Number of bamboos			Number of bamboos per clump			Diameter at eye height		
	Mini-mum	Ave-rage	Maxi-mum	Mini-mum	Ave-rage	Maxi-mum	Mini-mum	Ave-rage	Maxi-mum	Mini-mum	Ave-rage	Maxi-mum
Dendrocalamus strictus	150	280	400	2, 500	5, 000	8, 000	10	17	39	2. 4	3. 9	5. 9
Bambusa arundinacea	190	—	320	3, 000	—	7, 000	5	16	50	6. 0	9. 1	11. 9
Melocanna bambusoides				11, 000	—	18, 000				3. 1	5. 0	7. 1

	Air dry weight per culm (kg)	Remarks	Investigated place
Dendrocalamus strictus	3. 5	natural bamboo grove (mixed with trees)	Madhyapradesh, Balaghat
Bambusa arundinacea	10. 0	natural bamboo grove (not mixed with trees)	Hasanur, Madras Nillambur, Assam
Melocanna bambusoides	5. 0	natural bamboo grove (〃)	Cachar, Assam

Remark; Number of culms per clump sometimes are to 120 in natural bamboo grove (Bambusa Species), but in this case the culms are exceedingly congested.

On the clump-forming species of sympodial type, studies must be made synthetically on the number of bamboos in each clump and the space between clumps. In the groves of *Dendrocalamus* in India, generally at least 6 ~10 bamboos of 1~2 years old are left to stand in each clump with the felling cycle of three years.[2] The bamboo groves which have reached the cutting age, have 60~100 clumps per acre, 10~40 bamboos per clump and 20~30 feet for the space between clumps. The distribution of bamboos graded by diameters was investigated in India by the author et al. The results are as shown in Table 60.

On reference to the table, the density of *Melocanna* stand is almost equal to that of the grove of *Phyllostachys*, but *Dendrocalamus* and *Bambusa* species have bamboos standing more densely in one clump. Yet the clumps are spaced widely and the number of culms per ha is small. This propagating way of clump-forming species seems to be uneconomical from the view point of the use of the land. Yet, as already described in the section about classification, the growth and propagation of bamboos in the tropical regions are forced remarkably by the environment, to assume the clump form. For economical production, more research works are needed on the subject of proper arrangement of clumps and on the number of bamboos.

D-4. Cutting season

The best cutting season for harvest from their physiological view point and from the stand point of their quality needed in manufacturing furniture, etc. is autumn (October-November) in Japan. But for the pulp industry, the culms of poor quality in a bamboo grove can be cut in any month except the period when sprouts are developing.

The dry season is the cutting season for bamboos in the tropical regions, but the most suitable cutting season depends on further studies.

D-5. Thinning method of bamboo grove (felling method)

a. Bamboo grove of single culm forming species(*Phyllostachys* species) of monopodial type

It is, of course, necessary to leave a proper number of mature bamboos, and yet there are various methods of thinning. Some important ones will be described in the follows.

(1) Yearly felling (felling cycle; one year)

The yearly felling is a good method, because sprouts develop every year. Bamboos having reached the cutting age are cut every year, and in the case of the *Phyllostachys* species, about four-year-old ones are cut. The average felling ratio in one year in this case is 1/4(25%). When three-year-old bamboos are cut, the felling ratio becomes a little over 30 %. In this case intensive treatments such as fertilizing must be applied.

(2) Felling every second year (felling cycle; two years).

The felling is repeated every two years on culms that have reached the cutting age, and not done with those of two years. Therefore this method may be used in an inevitable case such as caused by labor conditions. The development of new bamboos usually alternates on and off year, and the felling is practised in the year of a good yield (on year).

(3) Felling every third year (felling cycle; three years).

The culms cut in this case include many old ones, and the yield is not three times as much as that in the case of yearly felling. Therefore this is never an advantageous method. But in case the area of a bamboo grove is wide, this method is to be employed according to the working condition.

(4) Felling every fourth year (felling cycle; four years).

In this case, more old culms are included in the yield because the felling is done every four years. This is not a recommendable method, because the number of newly grown culms and the volume of the yield decrease.

b. Bamboo grove of clump forming species of sympodial type

The age of full maturity has been put at 5~6 years so that the felling cycle for *Dendrocalamus* species lies between 1 and 5 years. A cycle of less than one year will mean cutting of immature culms and one of more than 5 years will mean a loss in culms which die before the next fellings. The ideal treatment would be to have a short felling cycle of 1~3 years.

In order to determine the best felling cycle it is necessary to consider intensity of labor, and agency of labor etc.

Intensity of labor; If the area is small and attention can be given to individual clumps, a one-year cycle is possible. With forest extending over thousands of acres, condition are different and a longer cycle becomes essential.

The agency of labor; This may be (a) departmental labor, (b) contractor,(c) lessee (d) permit holder. Under departmental labor, any felling cycle from 1 to 5 years can be adopted. In the cases, where the work is given to a contractor, lessee and permit holders, 4~5 year felling cycle is recommended.

Generally speaking, three or four felling cycles is usually applied to clump-forming species. In this case, the healthy culms, younger than two or three years old must be left.

D-6. Clear felling of bamboo grove (cutting all of bamboos)

a. Clear felling over the entire area

This is the simplest method requiring no supervision. But when all the culms are clearly felled at one time, the growth of rhizomes suddenly decrease, thus their productivity is reduced. It is disadvantageous to have those newly grown culms become slender after the clear felling.

Photo. 50. Slender new culms (average diam. 1 cm at eye height) coming out in July, 1952 after clear cutting in the grove of *Phyllostachys reticulata* in Feb. 1952 (average diam. 6 cm at eye height before clear cutting)

The author and his assistants made a research on the clear felling of the *Ph. reticulata* grove at the end of June, in August, November and February at the Kyoto Experimental Station.[4] A summary of the results are as follows:

(1) On the clear felling of mature bamboos except the growing shoots at the end of June; In this case the affect on the growth of the new culms is not so remarkable as it is for an entirely clear felling. The number of the new bamboos fully developed in the same year of clear

felling of mature bamboos decreased to 20 % and the total fresh weight of new ones decreased to 51 % for the culms developed in one year before clear felling.

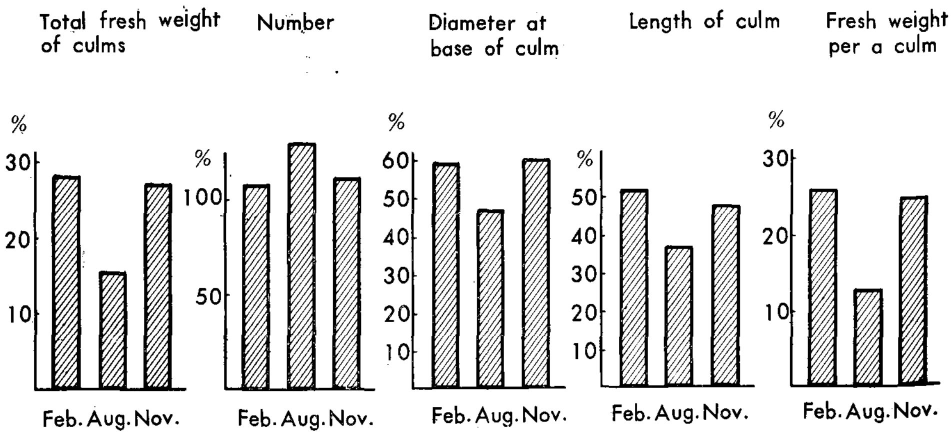
The number of new bamboos developed in the next year after clear felling, have shown the increment of about 1.3 times, and the total fresh weight had an increase of 30 %, but their diameter decreased to 20 %, compared with that of the bamboos before clear felling.

The elongation amounts of the new rhizomes grown in the same year of clear felling of mature bamboos, decreased to 62 % compared with the amounts of rhizomes before the clear felling, but that of the new rhizomes of the next year after the clear felling decreased to 80 % in comparison with the figure before the clear felling.

(2) On the entirely clear felling of the bamboos; The growth of the new bamboos developed in the next year after clear felling were most remarkably reduced in the August cutting-plot as compared with the February and the November-plots. This is as shown in Fig. 37.

The growth of the new rhizomes after clear felling was also mostly affected in the August-plot. In the August-plot, it was found that the apex of newly grown rhizomes abnormally came up above the ground and the new bamboos became slender. The elongation amounts of the new rhizomes in the August-plot were also the most inferior among these plots. Namely, it decreased to only 9 % in comparison with the amounts of one year before the clear felling. The growth of the new rhizomes in the November and the February-plots has shown a little better results than the August-plot, but they were reduced to half of

Fig. 37. Reduction ratio of newly grown culms



Investigated in Kamigamo, Kyoto, 1958

that before clear felling. It is inevitable that the poor growth of the new rhizomes should give bad affects on the development of the new bamboos in the next year.

If the treatment is neglected after clear cutting, it may take about 10 years until the size of newly grown bamboos gets as large as the parent original ones. But their rocovery of them can be promoted by fertilizing.

When the grove of the clump-forming species is clearly felled, the stock becomes impoverished and sometimes dies. This phenomenon is confirmed by the experiment on *Leleba multiplex* grove in Kyoto.

b. Partial clear felling

Thinning is hard to be carried out when a bamboo grove of a large area is felled by machines, and one is forced to adopt clear felling. But if a part of mature bamboos are left uncut, the influence of felling on the productivity becomes less compared with the case of entire clear felling. This can be applied to such a species as the *Phyllostachys* species that thrives mainly by the growth of buds of long rhizomes. It is desirable that the clear felling be done in the form of belt. The width of a belt varies according to the kinds of species or the property of the soil. This depends on further studies, but 20 m may be taken as a standard. The reason is that the distance of widely grown rhizomes in which nutrients are effectively translocated to new bamboos by the assimilation of remaining mature bamboos may appears to be within 10 m. As the clear felling leaves mature bamboos on either side of the felling area, the width of a clear felling belt should be within 20 m. Therefore, 20 or 40 meters is used for the width of the belt of the remaining bamaboo stand.

Remaining mature bamboos have to be better fertilized after clear cutting, in addition to the spring and summer applications. Clear felling should not be practised during the season from the time of sprouting to summer, season of rhizome growing, but it can be done through autumn into winter. If the treatments are properly done, the newly grown bamboos gain the parent original size in 5~7 years. In those districts where strong wind is prevailing, the direction of a belt should be considered in planning a clear felling, and the establishment of windbreaks must be kept in mind.

D-7. Cutting method of bamboos

a. Bamboo grove of single culm forming species (*Phyllostachys* species) of monopodial type

The young and healthy bamboos have to be left as above mentioned.

However the malformed, slender, diseased or otherwise useless culms should be cut, even young ones. Because leaving these poor culms, results in low production. The culms should be cut as low as possible, within 5 cm above the ground.

The culms generally are felled with a hatchet or a saw. After culms are felled, the branches are removed and the culms are carried to an open area or road side and piled (Photo. 51, 52). They are tied in bundles, and the number in a bundle depend upon the size of the culms. Those details were as shown in Table 36-3.

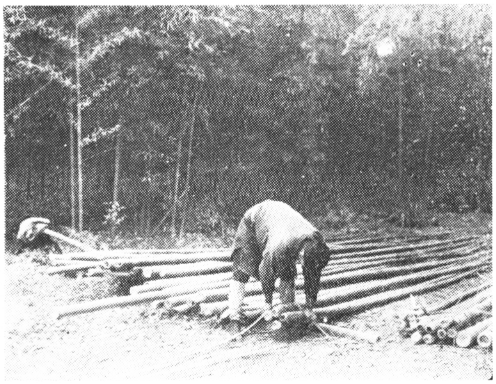


Photo. 51. Bundling work of bamboo cut

Photo. 52. The cut end of culms is variable, because the cutting method is varied accordrng to the size of culms

b. bamboo grove of clump forming species of sympodial type

i) The method that retains a number of mature culms to be a multiple of the number of new culms can be recommended. This method is practical and a check can be made when desired. Still more, this method also takes into account the varying requirements of clumps. For instance, the number of mature culms corresponding to that of newly grown culms (inmature culms) in a clump will be retained.

ii) Methods of felling of clumps are explained by P. N. Deogun as follows:[5]

(1) "Culms should be cut on a thinning principle so that those left are distributed over the rhizome system in such a way that the young shoots have sufficient support and do not bend over or fall. By this method the clump is kept open and workable."

(2) "The oldest and any deteriorating culms which cannot last for another cycle should be removed before any of the better are touched. Culms left should be the youngest and the most healthy."

(3) "Cutting on the periphery should be avoided as far as possible as

it is not in accordance with the principle of thinning and as it checks the outward growth of a clump."

(4) "Culms should be cut at a height of about 6~12″ above the ground and as far as possible just above a node so that a receptacle in which rain water may collect, is not form."

(5) "High cutting over 2′ to 3′ above ground level should be avoided as it not only results in an unnecessary waste but leads to difficult future working and possibly congestion."

(6) "Digging of culms with roots for sticks etc. should be avoided."

(7) "Culms and clumps in flower should be cut after the seed fall and not earlier."

(8) "Tending operations should be done with the felling by cutting any malformed, dead, diseased or otherwise useless culms, stumps, climbers, etc."

iii) Treatment of congested clumps; The basis of treatment should be a change of the conditions prevailing in the clump. This can be accomplished by cutting out such portions of the clump as are of no further use, viz., the central raised portion or the down hill portion where there is no chance for the new growth to extend, and by leaving more culms on the side of new growth, on the uphill side, etc. In case the clumps are not raised and are on an easy ground, and there is new growth all round, then a gap may be created and the central portion cut out leaving culms on the periphery only. In case the new growth is observed to be progressing in some particular direction, it should be helped by leaving more mature culms on that side. Felling of a congested clump is not so difficult as it appears; in fact it is quite easy if it is taken up properly. If there are no new culms, the area can be closed and the next year's growth watched and helped as described above.

D-8. Yearly culm yield

In the case of yearly felling, yearly culm yield is as follows; The yearly yield of culms varies according to soil conditions, treatment or sprouting conditions (on or off year). The average culm yield of yearly cutting per 1 ha is shown in Table 61.

This table reveals that the yearly yield of culms per 1 ha is 6~19 tons (or over) fresh weight in the grove of *Ph. edulis*, and 5~14 tons (or over) in that of *Ph. reticulata*. In the case of felling every other year, the yield will be about twice as much.

The yield of species that grow in the tropical regions especially in India, by felling every three years, is shown in Table 62.

Table 61. Annual yield of culms in the bamboo grove in Japan

(Per 1 ha.)

Species (grove)	Site grade	Annual yield			
		Number	*Soku*	Actual volume (m^3)	Fresh weight (ton)
Ph. edulis	Good	500	600	18.0	19.0
	Ordinary	800	400	12.0	13.0
	Poor	1,000	200	6.0	6.0
Ph. reticulata	Good	1,200	400	13.0	14.0
	Ordinary	1,500-2,000	200-300	7.0-10.0	7.0-11.0
	Poor	2,000	150	5.0	5.0
Ph. nigra	Ordinary	6,000-13,000	100-200	3.0-6.0	3.0-7.0

Table 62. Culm yield in round number by 3-year felling cycle of natural grove in India

	Yield at third year		Yield per year	
	per 1 acrs	1.0 ha	1 acre	1.0 ha.
	(ton)	(ton)	(ton)	(ton)
Dendrocalamus strictus	4.0	10.0	1.3	3.3
Bambusa arundinacea	6.0	15.0	2.0	5.0
Melocanna bambusoides	7.0	17.5	2.3	5.8

M. A. Huberman reported that the yield per 1 ha is 21 tons for *Melocanna* and 2.5~36.0 tons (three-year cycle) for *Bambusa*.[6] But generally the yields per 1 ha are low in the tropical regions. This may due to the fact that the bamboos are left naturally and no sufficient treatments taken for rearing. If proper thinning and fertilizing are practised, the increase in yield can certainly be expected.

References: 1) 3) 5) P. N. Deogun: Indian Forest. Vol. 11, No. 4, 1940.
2) Dr. S. Uno: Properties of Bamboo Culms and Their Utility, Nov., 1948.
4) Bulletin of the Kyoto University Forests. April, 1960.
6) Bamboo Silviculture, Unasylva. *13*: 1. 1959.

E. Method of improving Bamboo Groves and Breeding

a. Improvement of bamboo groves of inferior quality

Though a bamboo grove is poor, it can be altered into a good grove by the following methods of improving.

(1) Removing mixed shrub whenever necessary. Leaving the trees with

less extended branches, the rest are cut.

(2) Felling successively those older bamboos than 5~6 years, those injured by insects or diseases and also slender culms.

(3) Weeding, fertilizing and soil mulching (*kyakudo*) in Japan;sunny herbs of vigorous propagation are mowed and shade herbs may be left as they are. In fertilizing, apply the previously mentioned method in section C-2 of Part Ⅱ. Soil mulching (*kyakudo*) will be effective at place where the top soil is not deep.

"*Kyakudo*,, is the term used in Japanese, to express the mulching of working which the soil is brought from a nearby place.

(4) It is advisable to plant some trees of the Leguminosae species that grow rapidly on the free spaces or on the edges of a grove.

(5) Clear felling or reckless deforestation of a whole bamboo grove will result in lowering of its quality. In practice it must be carried out with great care .

(6) In a dry land or in an area where dry weather persists, irrigation is desirable.

b. Breeding

The important characteristics of the bamboo culm for utility are as follows;

1). It is very flexible and bent easily. 2). It has great toughness and splits easily. 3). It is hollow and light. 4). It has less swelling and shrinkage.

These characteristics are desirable for manufacturing many kinds of bamboo wares. However, further improvement of the quality of bamboo culm is still needed for the development of their more varied uses.

For instance, a thick wall and long internodes are required for making a slide rule. As pulp resources of paper and rayon production, the varieties with long fibers and thick walls are needed. A culm with a hardy character must be produced in order to avoid snow damages in cold regions.

An experiment for making the long-internode culm was made. The result is as shown in Photo. 48. Furthermore, the breeding should be considered. Several aspects of methods in breeding, such as interspecific crossing, the X-ray irradiation of seeds, the colchicine treatment of seeds or buds and a cutting have been described in the chapter of cytogenetic and other studies.

Many of the bamboo species in tropical regions have such characteristics as large sizes or thick walles, suitable for various uses. But their many branches grow from the lower nodes of culm, unprofitable for uses. As most of the *Bambusa* species have thorny branches, it is costly to remove them.

The suitable several species for crossing experiments are as follows.

1) *Semiarundinaria Kagamiana* Makinoi; Rikuchu-Dake

This species is found mostly in Iwate-Prefecture district in Japan. The culm has a comparatively big size and is hardy.

2) *Phyllostachys Makinoi* Hayatai; Kei-Chiku, or Taiwan-Madake

The best bamboo producing country is Formosa. The bamboos are cultivated for its culm use, resembles *Ph. reticulata* and forms a single culm. Its long fibers are suitable for pulp material. In both temperate and tropical regions, hence also in Japan, it can be grown and used for breeding.

3) *Schizostachyum Lumampao* Merr; BOHO, Locality; Philippine
4) *Gigantochloa Wrayi* Gamble; Locality; Malaya
5) *Bambusa procera* A. Chev.; Locality; Malaya
6) *Dendrocalamus giganteus* Munro: Locality; Malaya, Thiland, Burma, Cambodia, Viet-Num
7) *Dendrocalamus asper* Backer; Locality; Cambodia, Viet-Nnm, Malaya, Indonesia, Borneo
8) *Dendrocalamus Brandisii* Kurz; Locality; Cambodia, Thailand, Burma
9) *Leleba Tulda* Roxb; Locality; India, Burma, Thailand, Cambodia, Viet-Num

Table 63. Chemical component of a culm

(% on air dry matter)

Factors / Bamboo species	Crude cellulose	L-cellulose (in all cellulose)	Pentosan	Lignin	Extract of alcohol	Crude protein	Ash-content	Locality
1 *Phyllostachys reticulata*	42.20	72.03	22.27	28.30	5.47	9.09	1.07	Japan
2 *Phyllostachys nigra var Henonis*	43.52	70.25	26.81	28.90	6.85	8.36	2.03	〃
3 *Phyllostachys edulis*	35.26	66.86	26.50	30.13	4.27	9.10	1.53	〃
4 *Sasa paniculata*	53.18		26.59	21.71	+ 6.44		2.03	〃
5 *Dendrocalamus latiflorus*	34.36	66.90	25.31	33.17	5.20	4.94	1.70	Formosa
6 *Bambusa stenostachya*	44.85	77.25	19.42	28.58	4.81	7.74	1.74	〃
7 *Bambusa tulda*		67.70	18.39	28.04	+ 6.21		2.46	India
8 *Melocanna bambusoides*		62.60	14.04	25.32	+ 6.47		2.23	〃
9 *Pinus densiflora*	48.6~58.3	63.8~70.8	9.9~12.9	24.9~31.6	+ 1.9~3.9	0.8	0.1~0.4	Japan

1, 2, 3, 5, 6, ······by S. Uno **7, 8, ······by M. Takahama**
4, ······by G. Fukuyama **9, ······by N. Migita**
+·········extract of alcohol and benzene.

10) *Leleba Oldhami* Nakai; RYOKU-CHIKU Locality; Formosa

It is necessary for the breeding of bamboos to know the chemical component of culms and their fiber length, width and their ratio. A part of the data is shown in the Tables 63, 64.

Table 64. Fiber length, width and it's ratio (average)

Bamboo species \ Factors	(a) Fiber length (mm)	(b) Fiber width (mm)	(a/b) Ratio	Locality
1 { *Phyllostachys reticulata*	1.632	0.013	125.5	Japan
2 { *Phyllostachys nigra var. Henonis*	1.765	0.016	110.3	〃
3 { *Phyllostachys edulis*	1.562	0.012	130.2	〃
4 { *Sasa paniculata*	1.280	0.014	93.3	〃
5 { *Dendrocalamus latiflorus*	1.460	0.011	132.7	Formosa
6 { *Bambusa stenostachya*	1.479	0.012	123.3	〃
7 { *Phyllostachys Makinoi*	2.500	0,015	166.7	〃
8 { *Dendrocalamus strictus*	2.230	0.022	100.5	Burma
9 { *Melocanna bambusoides*	1.890	0.016	115.2	〃
10 { *Pinus densiflora*	3.32	0.039	85.1	Japan

1, 2, 3, ············by S. Uno　　5, 6, 7, ············by M. Nikuni
4, ············by G. Fukuyama　　8, 9, 10, ············by I. Ono

References; S. Uno; The Quality and Utility of Bamboo Culm, 1947.
G. Fukuyama; Research Bulletin of the HOKKAIDO University. 1955.
M. Takahama; Studies of manufacturing method for Cellulose Industry. 1959.
I. Ono; Bull. Univ. OSAKA Pref. Ser. B. Vo 1. 10. 1960.
N. Migita; Wood Chemistry. 1950.

F. Decorative Bamboo

There are many kinds of bamboo species used for decoration in Japan. The Japanese make especially good use of its esthetic qualities in exposed interior construction and in other types of decoration. The most attractive species are noted below.

a. Quadrangular culm

Quadrangular culms are made artificially in the suburbs of Kyoto city. These culms are produced by placing wooden frames over young shoots of

Phyllostachys edulis soon after they emerge from the ground. (Photo. 53—(1), (2)) The frames are constructed of 4 rough boards joined in 2 pairs by nails along the edges. The 2 halves of the frame are tied together with rope, placed over the new sprout grown about 30 cm in height and supported erectly by ropes extended from the top of the frame to adjacent culms or to stakes driven into the earth (Photo. 53—(3)). As the young shoot elongates through the frame it is restricted in its expansion by the walls of the frame and develops in quadrangular form.

Frames of square interior dimensions produce culms that are square in cross-section. Culms rectangular in cross section can be produced by using a frame constructed of 2 narrow and 2 wide boards. Quadrangular culms range in size from square dimensions of 3 to 10 cm to rectangular dimensions of about 3 x 10 cm or 5 x 15 cm. The frame board are about 1.5 cm in thickness and 4 m in length.

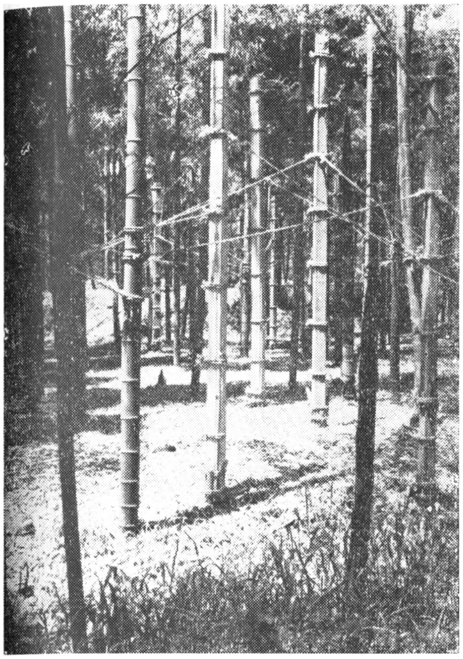
The interior dimension of frames must be equal to the exact size of the sprout at 5 cm in height above the ground.

If the interior dimensions of the wooden frame are too small to the complete expansion of the culm, one of its walls will fold into the hollow to form a quadrangular culm with a shallow or deep trough. When the shoots protrude above the top of the frame and complete its elongation from July to August, the frame is taken away from the shoot. (Photo. 53—(4))

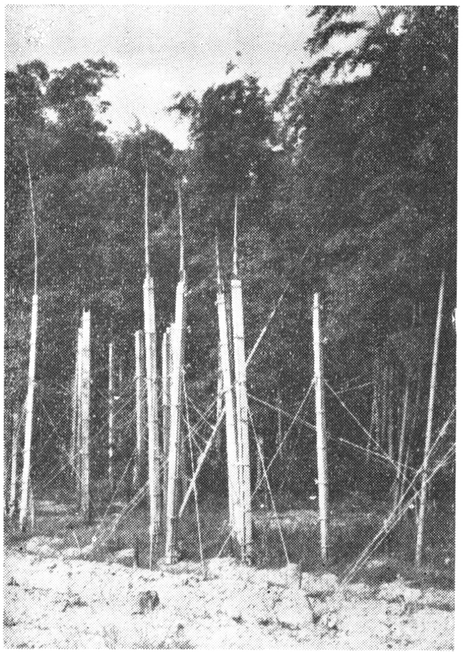
Photo. 53. The procedure of making of quadrangular bamboo

(1) The square frame placed over a new sprout of *Ph. edulis*.

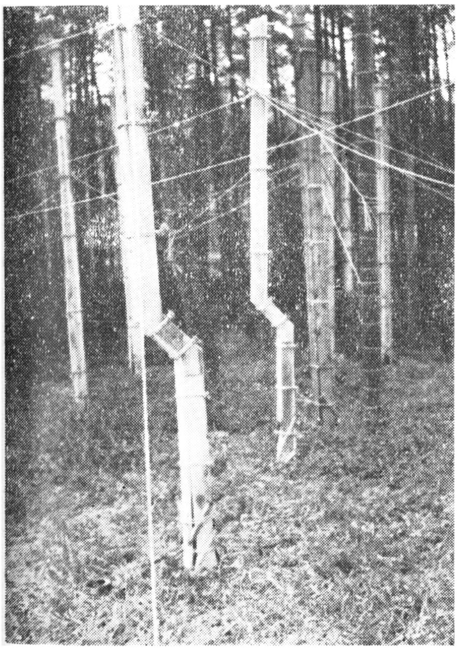
(2) The square frame is cramped by straw rope.



(3) The square frames are erectly supported by ropes.



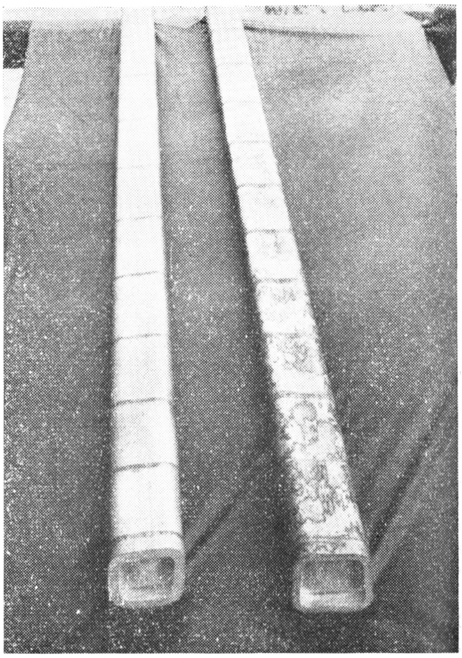
(4) The shoots growing square through the square frame.



(5) Making of curved quadrangular culm.

(6) Curved quadrangular culm from which the frame is removed.


(7) Spotting on the quadrangular bamboo.


(8) Quadrangular culm
Right: Spotted.
Left : Not spotted.

Most-attractive designs on the surface of culms after the frames are taken away are created by spotting or smearing them in July or August with a rubber brush and wet clay containing hydrochloric acid or sulfuric acid of 60%. The treated culm is mottled with areas of various shades of brown which stand out against the natural golden-yellow background. Quadrangular culms are commonly decorated in this fashion. A deep rich brown color is commonly used (Photo. 53—(7)(8)). These bamboos treated are cut off generally in November or December of the same year.

Natural markings which result usually from the development of fungi give bamboo culms a decorative value.

b. Curved culm

For special uses, a curved culm is created by attaching a rope to a young shoot at a point several feet above the ground, placing tension on the rope to cause the culm to lean, and then allowing the upper portion of the culm to return to its normal vertical position (Photo. 53—(5)(6)).

c. Tortoise-shell bamboo

The unique culms of the tortoise-shell bamboo (*KIKKO-CHIKU* in Japanese) or the Budda's-face bamboo (*BUTSUMEN-CHIKU* in Japanese),

Photo. 54. View of a grove of tortoise-shell bamboo in Mukomachi-Kyoto. (1958)

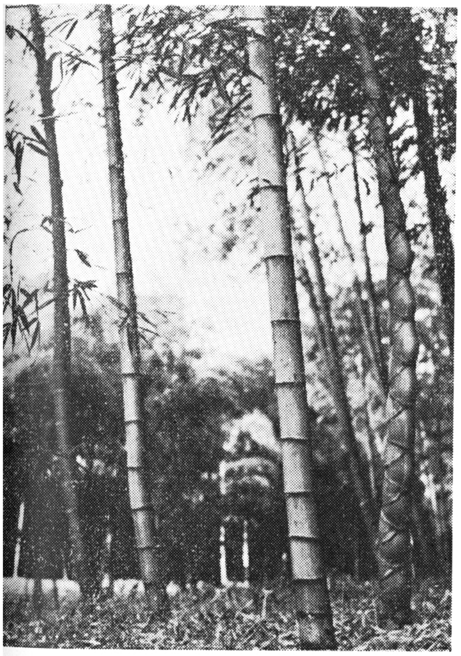


Photo. 55. Tortoise-shell bamboo developed accidentally from the grove of *Ph. edulis* in Mukomachi-Kyoto. (1958)

Tortoise-shell bamboo developed accidentally from the grove of *Ph. edulis* in Mukomachi-Kyoto (1958)

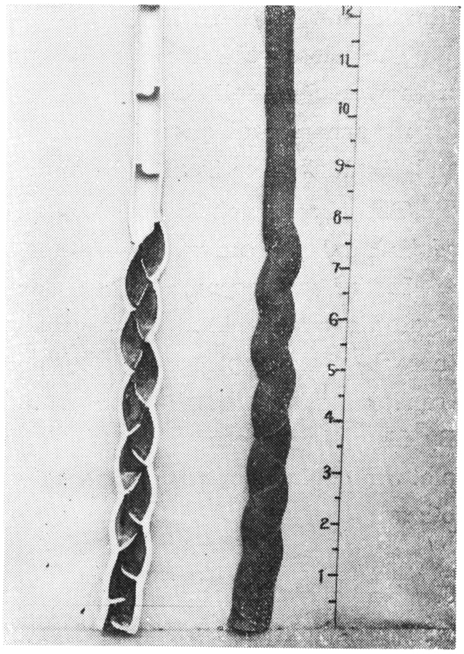


Photo. 56. *Phyllostachys edulis* var. *heterocycla form subconvexa* (The tortoise-shell bamboo)

Scale is marked at 5 cm intervals.

forma of *Ph. edulis*, are extensively used for decorative purposes. These culms are also used as exposed interior structural pieces in traditional style Japanese buildings. Both of these unique forms are grown as ornamentals (Photo. 54).

The form of Budda's face bamboo and tortoise-shell bamboo can not be distinguished clearly. Internodes of the lower part of the culms of these two formas are greatly reduced in length and are arranged obliquely in a zigzag fashion, each node merging with the node above on one side of the culm and with the node below on the opposite side. (Photo. 56). The oblique arrangement of the nodes is so strong in some culms that each node almost forms right angles with the nodes immediately above and below it. The internode is asymmetry. Namely, on one side of the internode is nil, on the opposite side is 6 to 14 cm long.

In culms of the tortoise-shell or Budda's-face bamboo, the lower portion is distorted as described above and this distortion ranges at about 2 meters from the ground. The mid portion is partly distorted. The upper portion grows straight normally. The girth of the culms is 15–40 cm. The cutting method for the harvest of culms is the same as explained in D. section "Harvesting" of Part. II

The photograph included here as Photo. 54 was taken in a small grove of the tortoise-shell bamboo that had been established in a farmer's garden for its ornamental qualities. But, it seems that the tortoise-shell bamboo and Budda's face bamboo have definitely not a hereditary nature.

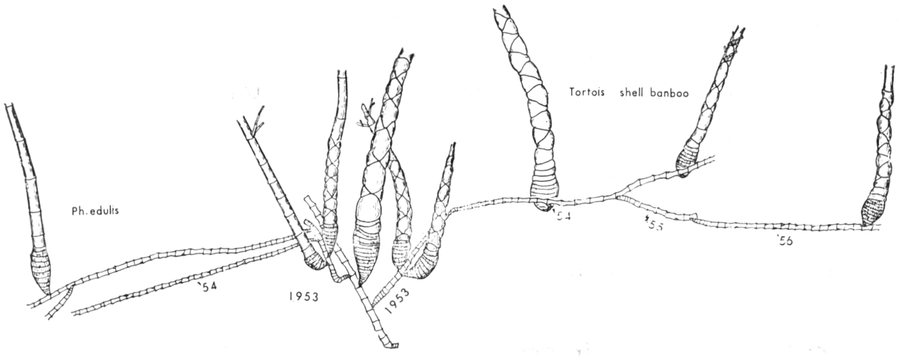
The photograph included here as Photo. 55. was taken in a grove of *Ph. edulis* bamboo from which tortoise-shell bamboo only accidentally developed.

In the bamboo nursery at Kamigamo Experimental Forest Station of Kyoto University, there are several plots of these unusual forms of *Ph. edulis*. In each of these plots, all or most of the bamboos that developed since the transplants were established about several years ago, are of the normal type. By distorting, the normal-type culms of *Ph. edulis* are produced in these plots irregularly we are looking forward to the normal production of a bizarre type after the bamboos become well established.

A very interesting phenomenon has occured as shown in Fig. 38 Photo. 57. Namely, the bamboo of this tortoise-shell form attached to a rhizome was transplanted in March, 1952 at Kamigamo Experimental Forest Station of Kyoto University. This bamboo was taken in the *Ph. edulis* grove from which only one of tortoise-shell bamboo accidentally developed. The newly grown culms developed every year and separated to the left and right thereafter. Namely, two new rhizomes from that rhizome in the next year developed, the one on the left producing bamboo of the normal type of *Ph. edulis* and the one to the right producing bamboos of the tortoise-shell type.

The rhizome producing normal-type bamboos of *Ph. edulis* branched and both branches continued to produce normal-type bamboos. Also the rhizome producing tortoise-shell bamboos on the right continued to produce all tortoise-shell bamboos. This phenomenon seems to be a somatic mutation or bud variation.

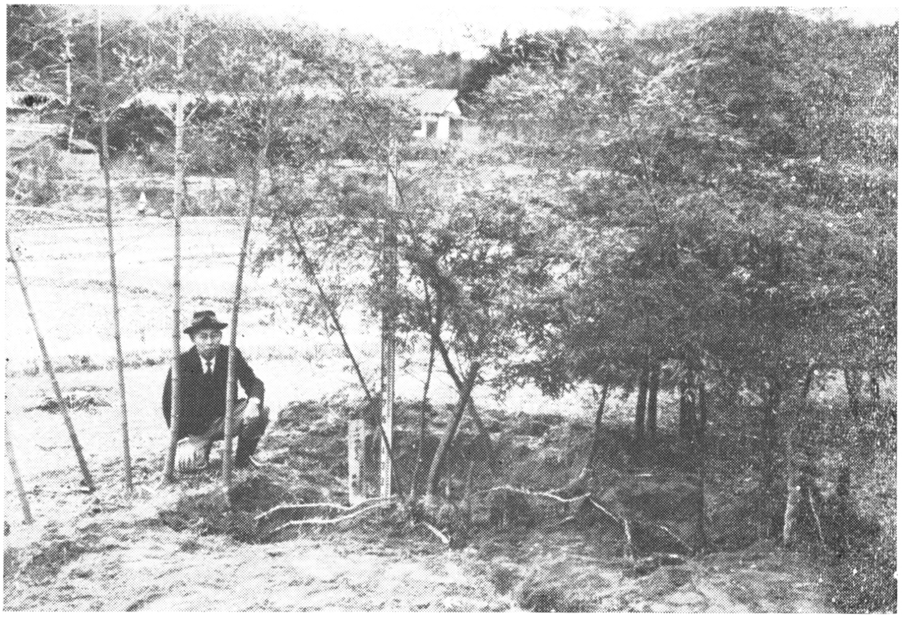
Fig. 38. Phenomenon of somatic mutation



Tortoise shell bamboo transplanted in March 1952
The whole view is shown in photo. 57

Place: Kamigamo. Kyoto
Investigated: Feb27. 1960

Photo. 57. Phenomenon of somatic mutation



Left; newly grown *Ph. edulis* bamboos Center; one tortoise-shell bamboo transplanted with rhizome. Right; newly grown tortoise-shell bamboo. (This is author at back side)

G. Injuries and Protection

G-1. Injuries by person.

Living rhizomes sometimes are stolen for making wares. They are used as handles for umbrellas, cutlery, ladies handbags, and other items. But when the young and healthy rhizomes are cut off, the bamboo grove produces only slender culms and its yield is reduced. Then cutting or digging of rhizomes should be avoided with the exception of old rhizomes.

G-2. Injuries by atomospheric agency

This is described as above at the "A-1. Climate and the Weather of 3-section Bamboo Cultivation".

G-3. Injuries by insects

a. Injuries by insect on living bamboos

(1) The larva of *Aprathea vulgaris* or *Melanotus cete* attacks the new growing sprouts and results in undeveloped bamboos mainly in the *Ph. reticulata* groves. The number of the injured sprouts depends on localities and years. The author and others have investigated this in a Kyoto district. The percentage of sprouts injured by insects, among the undeveloped sprouts was 25–35%. The injuries can be controlled by the spraying of B. H. C. on the small sprouts.

(2) Injuries by other insects are relatively insignificant. On a poor quality bamboo grove which has many over-5-year-old and unhealthy slender culms, the few and less vigorous ones are more liable to various injuries. But insect and disease problems are essentially non-existent in good groves of vigorously growing bamboos.

b. Injuries by insect on cut bamboos

Insects damage to stored bamboo. However, bamboos cut in the fall or winter can be stored in the open without treatment for at least 6–10 months without serious damage.

Control methods: The cut-culms piled up in a room should be smoked with methyl bromide by 1 lb per 1000 cubic feet ratio.

G-4. Death from flowering

The culms and controlling method of flowering are described above in section 3–Flowering of Part I.

G-5. Injuries by disease

Bamboos are strongly and have resistance to disease. Therefore damage by disease is relatively insignificant.

a. Method of controlling fungi

In order to control the development of fungi, the cut-culms must be steeped or boiled in liquid, 3 % of P. C. P. after the smoking treatment.

b. The utilization of diseased culms

The cuticle of the bamboo culm which is called in Japanese GOMA-DAKE, bears decorative black spots resembling GOMA (*Sesame* seeds), which spread over the entire surface of the culm. This variegated culm can be produced artificially. During spring, the upper parts of 3–5 year–old culms of *Phyllostachys edulis* are cut off, leaving the 4–5 branch–bearing nodes, and their bases are sawed half way through near the ground so that it remains alive. On account of the culm's reduced vitality the fungi (*Munkiella shiraiana*) naturally propagate sufficiently till autumn of the same year on the entire surface of the culm. This variegated culm is used for interior decoration of rooms or for material of furnitures.

The bamboo, called by the Japanese TORAFU–DAKE (tiger patterned bamboo) is a naturally variegated YASHA–DAKE species (*Semiarundinaria yashadake*), which is found in the provinces of Okayama, Japan. Some of these groves are designated as natural monuments. When the fungi (*Chaetosphaeria fusispora* (Kawamura) Hino) naturally develop on the entire surface of the culm of YASHA–DAKE, the blotchy marks, far bigger than that of GOMA–DAKE, cover the internodes. Its use is the same as GOMA–DAKE.